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Physical Oceanographic and Biological Data from the Study of the Flushing of Oyster (*Crassostrea virginica*) Larvae from Caraquet Bay, New Brunswick.

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PHYSICAL OCEANOGRAPHIC AND BIOLOGICAL DATA FROM THE STUDY OF THE FLUSHING OF OYSTER (*Crassostrea virginica*) LARVAE FROM CARAQUET BAY, NEW BRUNSWICK.

by

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ABSTRACT

Sephton, T.W. and D.A. Booth. 1992. Physical oceanographic and biological data from the study of the flushing of oyster (*Crassostrea virginica*) larvae from Caraquet Bay, New Brunswick. Can. Manuscr. Rep. Fish. Aquat. Sci. 2162:vii+61p.

The objective of the study was to examine the biological and oceanographic factors that influence the distribution and dispersion of the oyster larvae in Caraquet Bay, New Brunswick in 1988. This publication documents the materials and methods used in the study and presents all the accompanying biological and physical oceanographic field data that was collected.

RÉSUMÉ

Sephton, T.W. and D.A. Booth. 1992. Physical oceanographic and biological data from the study of the flushing of oyster (*Crassostrea virginica*) larvae from Caraquet Bay, New Brunswick. Can. Manuscr. Rep. Fish. Aquat. Sci. 2162:vii+61p.

L'objectif de cette recherche était d'étudier les facteurs biologiques et océanographiques qui influencent la distribution et la dispersion des larves d'huîtres dans la baie de Caraquet, Nouveau-Brunswick en 1988. Cette publication présente les matériels et méthodes utilisés lors de l'étude et toutes les données biologiques et océanographiques qui ont été récoltées.

INTRODUCTION

The northernmost commercially exploited population of eastern oyster, Crassostrea virginica (Gmelin), is located in Caraquet Bay, New Brunswick (47° 48' N, 65° 0' W) in the southern Gulf of St. Lawrence (Medcof 1961, Lavoie 1977). Following its decimation by Malpeque disease from 1950-1960 (Medcof 1961), a substantially smaller population reestablished itself on the public fishing ground and remains one of the most productive in the province (Lavoie 1977). Both the private and public sectors of the oyster industry rely on the public fishing ground as a source of seed oysters for enhancement and aquaculture purposes.

The natural population dynamics and recruitment processes are supplemented by the activities of aquaculturists with the passive collection of oyster spat with artificial collectors placed at different locations in the Bay just prior to the predicted spatfall. Both recruitment to the natural population and the success of the spat collectors varies from year to year, sometimes independently from one another, and is relatively unpredictable (Sephton and Bryan 1988, 1989). The objective of the present study was to examine the biological and oceanographic factors that influence the distribution and dispersion of the oyster larvae from spawning to settlement in Caraquet Bay, New Brunswick in 1988. A primary publication to that effect is being finalized (Booth and Sephton submitted) but because of its nature, it can only provide a summary and synthesis of the vast quantity of information that was collected during the ensuing field project. The objective of this publication is to document and place in the public domain all the biological and physical field data that was collected so that it is available for any future investigations for their research and analyses.

MATERIALS AND METHODS

Description of Study Site

Caraquet Bay is shallow semi-enclosed bay (Fig. 1) and is situated on the south shore of Baie des Chaleurs as shown in Figure 2. Freshwater from the

surrounding catchment basin enters the Bay via two main rivers: Rivière Caraquet and Rivière du Nord, with the former having an average summer discharge of 3 m^3s^{-1} and a catchment area 3 times larger than the latter. A third smaller river enters the Bay on the south shore and is 10 times smaller than Rivière Caraquet. Various dykes collect discharge from the peat moss harvesting area along the north side of the Bay.

The average water depth at low tide is about 2 m and the mean tidal range is 1.4 m. The resulting tidal prism is about half the mean volume of the Bay. Figure 3 shows the extent of the intertidal zone and water depth contours of the Bay as they would appear at low tide. A dune (known locally as La Dune de Maisonette) stretches across the mouth of the Bay and is exposed at low tide while a bank lies along the inner edge of the inner channel.

Oyster Larvae Sampling

Ten sample stations within the Bay, one in the channel and one outside the Bay (total of 12) were established for sampling the oyster larvae as shown in Figure 4. A 750 l integrated plankton sample was collected at each station by lowering and raising a submersible bilge pump from the surface to 0.2 m above the bottom during a 10 min interval. At stations 8, 11 and 12 samples were collected from two depth strata: the upper (0-2 m) and lower (3-5 m) stratum. The oyster larvae were concentrated by filtering through a 100 µm Nitex mesh screen and were preserved in buffered sea water formalin. Salinity and temperature were measured at each station at the time of larval sampling.

Larval samples were obtained on the following days (Julian dates) : 189, 194-196, 201-203 and 206-215 (July 7 - August 2, 1988). A double circuit of the sample stations was completed on days 206-215 with the exception of 209 and 215 because of mechanical failure. A full circuit of the stations took 3-4 h and this logistical constraint prevented the collection of replicate samples at each station. All larvae in each sample were identified and enumerated. Samples with large concentrations (> 250 larvae m^{-3}) were subsampled.

Six larval developmental stages were identified from the samples based on the descriptions given by Drinnan and Stallworthy (1979). The names and respective shell heights distinguishing the stages are as follows: early straight hinge (EH) 60 μm - 84 μm; late straight hinge (LH) 85 μm - 104 μm; incipient umbo 105 μm - 149 μm; early umbo (EU) 150 μm - 199 μm; late umbo (LU) 200 μm - 350 μm; mature (M) 350 μm and larger. The first two larval stages (EH and LH) (60 μm - 104 μm) were not collected quantitatively because of the mesh size (100 μm) used to screen the larvae and, consequently, their densities were underestimated in this study.

Larval Data Presentation

Table 1 presents the larval abundances, converted to number m^{-3}, of each larval stage as well as the total densities for each sample collected at each station on each sample date. The time the sample was collected is also noted in Table 1.

Figures 5 to 13 show the density contoured plots of the larval distribution scaled as a function of the percentage of the total larval abundance of the samples. These hand contoured maps show the movement of the larvae between selected dates and on the same date on different tides. The midpoint state of the tide during the larval sampling period is also shown on the Figures.

Oceanographic Measurements

The oceanographic instruments were deployed in the Bay for that time period which coincided with the oyster larvae (Julian dates 185-228, July 3 to 15 August, 1988) and consisted of 7 current meters on 6 subsurface moorings as shown in Figure 14. Four moorings, labelled A-D (Fig. 14), were installed and supported Aanderaa current meters at a depth of 3 m below low water. Mooring B, in the channel, also had a second Aanderaa current meter at 1 m above the bottom in a low water depth of 5.5 m. Current meters on moorings A and B were models RCM7 and those on moorings C and D were the older model RCM4's but all had paddle rotors. Two InterOcean model S4 electromagnetic current meters were installed on frames at 1 m from the bottom at sites labelled S and N in the inner part of the Bay as shown in Figure 14. Although the base

of the frame was constructed of steel, the vertical rod supporting the S4's was of stainless to minimize magnetic effects. The S4 at mooring N was only installed on 28 July.

Lagrangian water currents were measured with small drifting buoys, each equipped with a narrow mast and a simple windowblind drogue of dimensions 0.8 m X 0.6 m. The drogue was centred at a depth of 0.5 m. Based on frontal areas, slippage due to wind drag was estimated to be 4 X 10^{-3} X surface wind velocity. Groups of up to 20 buoys were followed by boat. At intervals of about 1 hour, positions of the buoys were measured with a microwave Motorola MiniRanger system on the boat. The buoys were tracked during a complete semidiurnal tidal cycle on two days, July 6 and 29 (Julian date 188 and 211, respectively). Buoys were also tracked for periods of 2 and 10 hours on 8 other days between July 5 and August 4, 1988.

Temperature and salinity measurements were made with an Applied Microsystem STD12 (STD), equipped with a shallow water pressure transducer. Uppermost samples were recorded with the sensors at about 0.3 m below the surface. The grid of 12 stations was covered daily during the later stages of larval development. STD measurements were made near the drifting buoys at other times.

An Aanderaa water level (tide) recorder (model WLR7) equipped with a 70 m transducer and installed at Caraquet Harbour as shown in Figure 14 (labelled T). An Aanderaa meteorological station was installed at Oyster Point (Fig. 14, labelled M) to measure wind direction and speed, solar radiation and atmospheric pressure, and air temperature and humidity.

Oceanographic Data Presentation

The directional velocity (water current speed), water temperature and salinity data collected by the different current meters are summarized graphically in Figures 16 to 29. Salinity data is presented using the practical salinity scale (PSS) which is the new unitless scale for its measurement. The current meters were cleaned by diver at the end of July, but the rotors on the meters in the channel (B) were fouled with weed

on recovery in August. Fouling also affected some of the conductivity probes and reduced some of the observed salinities which resulted in that data being discarded from subsequent analysis. Table 2 summarizes the water temperature and salinity (PSS) data collected at each larval sampling station with the STD.

The drifting buoy data are summarized on Figures 36 to 46. Each buoy position is noted (as a "+") on the Figures but the times (Universal Time Coordinate) (UTC) given represent the mid time, to the nearest 10 min., for the group. This was because a complete positioning tour of the group of buoys took at least 30 min. to accomplish. Groups were positioned at approximately hourly intervals and dotted lines have been added to facilitate identifying displacements when more than one deployment was tracked on the same day.

The tide gauge data collected at Caraquet Harbour wharf are summarized in Figure 15. One decibar is approximately equal to 1 m of seawater. The Aanderaa meteorological station data collected at Oyster Point are summarized for wind direction and speed in Figures 30 to 33, solar radiation and atmospheric pressure in Figure 34, air temperature and humidity in Figure 35.

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TABLE 1. Abundance of each oyster larval growth stage and total larval concentration (number m^{-3}) for each sample collected at each station in Caraquet Bay, New Brunswick in 1988. Abbreviations for larval stages are: EH = early straight hinge, LH = late straight hinge, IU = incipient umbo, EU = early umbo, LU = late umbo and M = mature. The water depth (range) where the integrated sample was obtained is also shown.

DATE (1988)	JULIAN DATE	TIME hrs	SITE #	DEPTH m	LARVAL STAGE EH	LH	IU	EU	LU	M	TOTAL # PER m3
07-Jul	189	1100	2	0-1	0	1	0	0	0	0	1
		1130	3	0-1	0	0	1	0	0	0	1
		1230	4	0-1	0	0	0	0	0	0	0
		1300	5	0-1	0	0	0	0	0	0	0
		1330	6	0-1	0	0	0	0	0	0	0
		1400	7	0-1	0	0	0	0	0	0	0
12-Jul	194	1040	1	0-2	0	3	0	0	0	0	3
		1102	2	0-1	0	0	0	0	0	0	0
		1120	3	0-1	0	0	0	0	0	0	0
		1141	5	0-2	0	0	0	0	0	0	0
		1156	6	0-2	0	4	0	0	0	0	4
		1210	7	0-2	0	0	0	0	0	0	0
		1227	8	0-2	0	0	0	1	0	0	1
		1242	9	0-2	0	0	0	0	0	0	0
		1254	10	0-2	0	1	0	0	0	0	1
		1312	11	0-2	0	4	0	0	0	0	4
13-Jul	195	905	1	0-2	0	0	0	0	0	0	0
		927	2	0-1	4	6	0	0	0	10	20
		942	3	0-1	0	0	0	0	0	0	0
		957	4	0-2	1	44	7	0	0	0	52
		1048	5	0-2	0	1	1	0	0	0	2
		1030	6	0-2	0	1	3	0	0	0	4
		1016	7	0-2	0	20	4	0	0	0	24
		1108	8	0-2	0	1	0	0	0	0	1
		1124	9	0-2	0	0	1	0	0	0	1
		1139	10	0-2	0	0	0	0	0	0	0
		1206	11	0-2	0	0	0	0	0	0	0
14-Jul	196	923	1	0-2	0	0	0	0	0	0	0
		946	2	0-1	0	0	0	0	0	0	0
		1004	3	0-1.5	0	0	3	0	0	0	3
		1019	4	0-1.5	0	0	0	0	0	0	0
		1117	5	0-2	0	1	1	0	0	0	2
		1102	6	0-2	0	0	6	0	0	0	6
		1046	7	0-1.5	0	0	0	0	0	0	0
		1138	8	0-2	0	0	1	0	0	0	1
19-Jul	201	930	1	0-2	0	0	0	0	0	0	0
		955	2	0-2	0	0	332	414	3	0	749
		1015	3	0-2	0	0	0	3	1	0	4
		1031	4	0-2	0	0	1	6	0	0	7
		1119	5	0-3	0	0	7	7	0	0	14
		1103	6	0-3	0	0	1	4	0	0	5
		1049	7	0-2	0	0	180	268	4	0	452
		1137	8	0-2	0	0	11	6	0	0	17
		1154	9	0-3	0	0	0	0	0	0	0
		1209	10	0-2	0	0	40	62	0	0	102
		1230	11	0-2	0	0	18	11	0	0	29
		1300	12	0-2	0	0	27	0	0	0	27
20-Jul	202	1203	1	0-1.5	0	0	6	9	0	0	15
		1144	2	0-1.5	0	0	96	91	0	6	193
		1224	3	0-2	0	0	14	10	0	0	24
		1126	4	0-2	0	11	511	431	11	0	964
		1240	5	0-2	0	0	0	0	0	0	0
		1256	6	0-3	0	0	4	6	0	0	10
		1105	7	0-2	0	0	704	499	23	0	1226
		1322	8	0-2	0	1	16	11	0	0	28
		1340	9	0-2	0	0	340	409	0	0	749
		1043	10	0-2	0	0	40	55	10	0	105
		1404	11	0-3	0	0	116	45	0	0	161

TABLE 1. Continued.

DATE (1988)	JULIAN DATE	TIME hrs	SITE #	DEPTH m	LARVAL STAGE EH	LH	IU	EU	LU	M	TOTAL # PER m3
21-Jul	203	1300	1	0-2.5	0	0	0	10	1	0	11
		1245	2	0-1	0	0	1	9	4	0	14
		1217	3	0-2	0	0	216	420	79	0	715
		1232	4	0-1.5	0	0	274	1330	548	0	2152
		1156	5	0-2.5	0	0	91	454	170	0	715
		1139	6	0-3	0	0	31	91	20	3	145
		1124	7	0-2	0	0	386	1089	409	0	1884
		1039	8	0-2	0	0	40	38	0	0	78
		1056	9	0-3	0	0	454	704	113	0	1271
		1109	10	0-2.5	0	0	454	1634	363	0	2451
		1020	11	0-2	0	0	34	35	0	11	80
		959	12	0-2	0	1	0	3	0	0	4
22-Jul	204	729	5	0-3	0	3	37	119	31	0	190
		716	6	0-3	0	0	3	23	1	0	27
		701	10	0-2	0	0	295	862	91	0	1248
		645	11	0-2	0	0	3	3	0	0	6
24-Jul	206	1235	1	0-1.5	0	0	0	9	7	0	16
		1255	2	0-1.5	0	0	3	3	16	0	22
		1320	3	0-2	0	1	11	38	81	16	147
		1340	4	0-2	0	23	34	148	142	11	358
		1355	5	0-2	0	0	176	142	91	23	432
		1414	6	0-2	0	6	40	119	187	17	369
		1430	7	0-2	0	0	68	91	193	23	375
		1455	8	0-2	0	6	62	96	176	11	351
		1510	8	3-5	0	0	34	182	556	68	840
		1525	9	0-2	0	68	567	726	567	45	1973
		1542	10	0-1.5	0	11	23	227	352	0	613
		1110	11	0-2	0	28	96	170	62	0	356
		1100	11	5-7	0	0	17	71	62	3	153
		1200	12	0-2	0	0	3	3	0	0	6
		1150	12	4-6	0	0	0	3	0	0	3
24-Jul	206	1710	1	0-1.5	0	0	0	0	0	0	0
		1754	2	0-1.5	0	0	0	9	11	3	23
		1803	3	0-1.5	0	0	48	145	182	6	381
		1813	4	0-1.5	3	17	9	28	99	0	156
		1827	5	0-2	0	0	45	272	329	0	646
		1840	6	0-2	0	0	11	17	23	3	54
		1848	7	0-2	0	0	3	3	0	0	6
		1902	8	0-2	0	0	54	119	88	99	360
		1904	8	3-5	0	0	0	20	40	0	60
		1932	10	0-1.5	0	0	14	88	14	0	116
		1710	11	0-2	0	0	17	102	105	3	227
		1720	11	5-7	0	0	0	0	9	0	9
25-Jul	207	1255	1	0-1.5	0	0	0	0	0	0	0
		1305	2	0-1.5	0	1	1	6	9	1	18
		1318	3	0-2	0	0	0	0	0	0	0
		1335	4	0-2	0	0	1	3	3	10	17
		1350	5	0-2	0	0	148	431	726	91	1396
		1407	6	0-2	0	0	0	28	116	3	147
		1422	7	0-2	0	0	68	454	522	136	1180
		1443	8	0-2	0	0	9	79	105	9	202
		1445	8	3-5	0	0	34	85	199	28	346
		1505	9	0-2	0	0	45	522	499	113	1179
		1525	10	0-1.5	0	0	352	352	204	0	908
		1225	11	0-2	0	3	1	6	11	0	21
		1215	11	5-7	6	6	17	108	159	0	296
		1145	12	0-2	0	0	1	9	1	0	11
		1155	12	4-6	0	0	0	9	4	1	14

TABLE 1. Continued.

DATE (1988)	JULIAN DATE	TIME hrs	SITE #	DEPTH m	LARVAL STAGE EH	LH	IU	EU	LU	M	TOTAL # PER m3
25-Jul	207	1733	1	0-1	0	1	0	1	7	0	9
		1750	2	0-1	0	0	3	7	17	10	37
		1800	3	0-1.5	0	0	1	11	34	16	62
		1815	4	0-1.5	0	0	0	1	1	0	2
		1830	5	0-2	0	0	4	18	20	11	53
		1845	6	0-2	0	10	0	0	0	0	10
		1900	7	0-1.5	0	0	3	9	17	3	32
		1915	8	0-2	0	3	9	23	21	7	63
		1926	8	3-5	0	0	91	738	1163	193	2185
		1940	9	0-2	0	0	0	0	1	0	1
		1955	10	0-1.5	0	1	1	14	37	11	64
		1655	11	0-2	0	0	0	0	1	0	1
		1705	11	5-7	0	0	6	37	57	14	114
26-Jul	208	852	1	0-2	0	0	1	0	6	3	10
		912	2	0-1	0	0	1	0	0	1	2
		925	3	0-1.5	0	0	3	10	21	26	60
		941	4	0-1.5	0	0	0	3	16	14	33
		955	5	0-2	0	0	1	0	0	1	2
		1010	6	0-2	0	0	1	0	0	1	2
		1025	7	0-1.5	0	0	20	37	48	94	199
		1045	8	0-2	0	0	0	0	0	0	0
		1055	8	3-5	0	0	0	0	0	0	0
		1110	9	0-2	0	0	0	0	0	0	0
		1123	10	0-1.5	0	0	0	0	0	0	0
		815	11	0-2	0	1	30	71	92	121	315
		825	11	5-7	0	0	1	1	9	0	11
		740	12	0-2	0	0	0	1	6	1	8
		750	12	4-6	0	0	3	13	7	4	27
26-Jul	208	1343	1	0-2	0	0	0	0	0	0	0
		1400	2	0-1.5	0	0	1	1	24	4	30
		1412	3	0-2	0	0	0	13	7	28	48
		1430	4	0-2	0	0	0	27	87	135	249
		1445	5	0-2	0	0	4	9	16	1	30
		1500	6	0-2	0	0	3	4	6	0	13
		1517	7	0-2	0	0	0	0	4	6	10
		1546	8	3-5	0	0	0	3	4	13	20
		1536	8	5-7	0	0	1	9	4	0	14
		1600	9	0-2	0	6	62	233	329	96	726
		1633	10	0-2	0	0	3	1	0	0	4
		1320	11	0-2	0	3	11	48	58	27	147
		1308	11	5-7	0	0	28	45	74	31	178
27-Jul	209	1001	1	0-2	0	0	4	1	0	3	8
		1021	2	0-.5	0	0	3	9	14	11	37
		1042	3	0-1	0	0	3	9	17	20	49
		1104	4	0-1	0	0	0	0	0	0	0
		1127	5	0-2	0	0	1	1	11	9	22
		1142	6	0-2	0	6	17	40	96	210	369
		1201	7	0-1.5	0	3	0	0	0	7	10
		1256	8	3-5	0	1	4	18	37	24	84
		1307	8	0-2	0	3	6	34	30	54	127
		1322	9	0-2	0	1	1	11	33	9	55
		1340	10	0-1.5	0	0	1	1	3	3	8
		922	11	5-7	0	3	0	31	40	68	142
		933	11	0-2	0	0	6	91	193	62	352

TABLE 1. Continued.

DATE (1988)	JULIAN DATE	TIME hrs	SITE #	DEPTH m	LARVAL STAGE EH	LH	IU	EU	LU	M	TOTAL # PER m3
28-Jul	210	1046	1	0-2	0	0	0	1	1	3	5
		1104	2	0-1	0	0	1	0	6	4	11
		1118	3	0-1.5	0	0	1	0	10	47	58
		1133	4	0-1.5	0	0	3	17	37	241	298
		1146	5	0-2	0	0	0	1	9	4	14
		1204	6	0-2	0	11	0	102	204	284	601
		1217	7	0-1.5	0	0	0	23	306	295	624
		1238	8	0-2	0	0	0	51	119	108	278
		1249	8	3-5	0	0	51	62	108	79	300
		1304	9	0-2	0	1	4	16	10	6	37
		1316	10	0-1.5	0	0	1	4	23	31	59
		1005	11	0-2	0	0	10	16	27	20	73
		1016	11	5-7	0	0	0	0	0	4	4
		932	12	0-2	0	0	0	18	28	10	56
		920	12	3-5	0	0	0	4	10	3	17
28-Jul	210	1532	1	0-2	0	0	6	62	102	193	363
		1548	2	0-1.5	0	0	91	45	499	862	1497
		1603	3	0-2	0	0	6	4	14	30	54
		1617	4	0-2	0	0	45	363	590	885	1883
		1634	5	0-2	0	0	7	16	13	24	60
		1646	6	0-2	0	0	0	4	30	21	55
		1711	7	0-2	0	0	57	148	148	352	705
		1730	8	3-5	0	0	1	7	40	10	58
		1741	8	0-2	0	0	13	17	24	28	82
		1755	9	0-2	0	1	3	7	23	17	51
		1814	10	0-1.5	0	4	13	10	16	34	77
		1500	11	5-7	0	0	0	0	16	1	17
		1512	11	0-2	0	3	10	24	34	88	159
29-Jul	211	1102	1	0-1	0	0	0	0	2	7	9
		1122	2	0-1	0	0	0	0	2	9	11
		1140	3	0-1.5	0	0	16	18	20	50	104
		1154	4	0-1	0	0	5	5	48	164	222
		1211	5	0-2	0	0	118	143	136	168	565
		1225	6	0-2	0	0	20	32	98	18	168
		1242	7	0-1	0	0	0	0	2	0	2
		1300	8	3-5	0	0	5	0	11	5	21
		1311	8	0-2	0	0	0	2	5	0	7
		1327	9	0-2	0	0	0	0	0	0	0
		1345	10	0-1	0	0	0	11	23	18	52
		1015	11	5-7	0	0	5	36	68	70	179
		1027	11	0-2	0	0	2	0	7	0	9
		1410	12	4-6	0	0	0	0	0	0	0
		1420	12	0-2	0	0	0	0	0	0	0
29-Jul	211	1627	1	0-2	0	0	14	30	50	32	126
		1643	2	0-2	0	0	3	21	75	187	286
		1701	3	0-2	0	0	11	16	40	21	88
		1710	4	0-2	0	0	0	21	165	11	197
		1730	5	0-2	0	0	0	1	7	4	12
		1743	6	0-2	0	0	0	11	37	0	48
		1757	7	0-2	0	0	0	3	37	57	97
		1815	8	3-5	0	0	0	6	3	0	9
		1826	8	0-2	0	0	0	0	0	0	0
		1840	9	0-2	1	1	7	13	23	7	52
		1854	10	0-2	0	1	16	6	31	10	64
		1551	11	5-7	0	0	2	5	5	2	14
		1602	11	0-2	0	0	5	2	2	5	14

TABLE 1. Continued.

DATE (1988)	JULIAN DATE	TIME hrs	SITE #	DEPTH m	LARVAL STAGE EH	LH	IU	EU	LU	M	TOTAL # PER m3
30-Jul	212	1130	1	0-2	0	0	0	0	1	0	1
		1146	2	0-1	0	0	7	6	6	72	91
		1205	3	0-1.5	0	0	7	0	9	4	20
		1220	4	0-1.5	0	0	4	7	4	65	80
		1235	5	0-2	0	0	38	44	24	20	126
		1249	6	0-2	0	0	38	44	34	156	272
		1307	7	0-1.5	0	0	1	6	4	3	14
		1327	8	3-5	0	0	84	27	34	6	151
		1337	8	0-2	0	0	1	9	6	17	33
		1351	9	0-2	0	0	16	7	3	1	27
		1406	10	0-2	0	0	34	24	26	96	180
		1055	11	5-7	0	0	1	0	0	0	1
		1105	11	0-2	0	0	27	16	21	30	94
		1020	12	4-6	0	0	0	0	0	0	0
		1130	12	0-2	0	0	1	1	0	1	3
30-Jul	212	1700	1	0-2	0	0	62	57	45	125	289
		1715	2	0-2	0	0	60	20	47	157	284
		1729	3	0-2	0	0	118	35	27	64	244
		1744	4	0-2	0	0	138	38	51	143	370
		1800	5	0-2	0	1	0	1	0	1	3
		1835	6	0-2	0	0	0	0	0	0	0
		1817	7	0-2	0	3	122	24	21	40	210
		1847	8	3-5	0	0	7	13	7	6	33
		1857	8	0-2	0	0	0	0	0	0	0
		1914	9	0-2	0	0	51	17	23	48	139
		1928	10	0-2	0	0	6	0	1	4	11
		1620	11	5-7	0	0	10	13	14	10	47
		1631	11	0-2	0	0	0	0	0	1	1
31-Jul	213	725	1	0-2	0	0	153	74	96	130	453
		740	2	0-2	0	0	221	40	79	301	641
		754	3	0-2	0	1	67	20	26	30	144
		815	4	0-2	0	0	9	0	1	9	19
		827	5	0-2	0	0	18	18	1	4	41
		857	6	0-2	0	0	28	0	0	1	29
		911	7	0-2	0	6	306	23	68	79	482
		935	8	3-5	0	0	0	6	1	1	8
		945	8	0-2	0	0	7	4	3	0	14
		1004	9	0-2	0	0	24	55	1	40	120
		1022	10	0-2	0	0	6	4	1	0	11
		710	11	5-7	0	0	0	4	1	4	9
		700	11	0-2	0	0	0	0	0	0	0
31-Jul	213	1330	1	0-1.5	0	0	0	0	7	6	13
		1345	2	0-1	0	0	4	0	0	1	5
		1400	3	0-1	0	0	40	23	27	44	134
		1415	4	0-1	0	0	0	0	4	4	8
		1435	5	0-2	0	0	0	0	3	4	7
		1452	6	0-2	0	0	0	0	14	26	40
		1508	7	0-1.5	0	0	74	81	62	88	305
		1530	8	3-5	0	0	0	0	0	0	0
		1540	8	0-2	0	0	0	0	0	0	0
		1600	9	0-2	0	0	10	11	3	1	25
		1614	10	0-1.5	0	0	133	50	13	68	264
		1311	11	5-7	0	0	9	3	1	0	13
		1300	11	0-2	0	0	9	9	0	0	18

TABLE 1. Continued.

DATE (1988)	JULIAN DATE	TIME hrs	SITE #	DEPTH m	LARVAL STAGE EH	LH	IU	EU	LU	M	TOTAL # PER m3
01-Aug	214	820	1	0-2	0	0	60	33	16	133	242
		834	2	0-2	0	0	148	77	16	47	288
		846	3	0-2	0	0	3	38	1	3	45
		901	4	0-2	0	0	91	68	7	20	186
		915	5	0-2	0	0	1	0	1	1	3
		930	6	0-2	0	0	0	7	0	0	7
		943	7	0-2	0	0	17	81	38	27	163
		1002	8	3-5	0	0	3	1	1	0	5
		1012	8	0-2	0	0	3	13	3	0	19
		1030	9	0-2	0	0	0	0	0	0	0
		1043	10	0-1.5	0	0	23	167	27	27	244
		750	11	5-7	0	0	1	3	0	1	5
		800	11	0-2	0	0	0	3	1	0	4
		1104	12	4-6	0	0	0	0	1	1	2
		1115	12	0-2	0	0	3	7	3	0	13
01-Aug	214	1420	1	0-1.5	0	0	0	1	3	0	4
		1435	2	0-1	0	0	0	17	6	11	34
		1452	3	0-1	0	0	20	102	11	48	181
		1507	4	0-1	0	0	74	113	62	102	351
		1532	5	0-2	0	0	148	91	17	34	290
		1550	6	0-2	0	0	306	216	11	79	612
		1605	7	0-1.5	0	0	318	182	57	125	682
		1624	8	3-5	0	0	65	94	9	9	177
		1634	8	0-2	0	0	136	68	51	17	272
		1650	9	0-2	0	0	187	85	0	17	289
		1705	10	0-2	0	0	340	862	136	91	1429
		1345	11	5-7	0	0	182	91	23	6	302
		1355	11	0-2	0	0	182	74	17	34	307
02-Aug	215	1312	1	0-1.5	0	0	65	34	23	14	136
		1326	2	0-1	0	0	10	47	10	17	84
		1342	3	0-1	0	0	68	79	23	45	215
		1358	4	0-1	0	0	11	13	9	4	37
		1417	5	0-1.5	0	0	204	267	28	102	601
		1433	6	0-2	0	6	170	62	40	6	284
		1452	7	0-1	0	0	102	170	142	57	471
		1517	8	3-5	0	0	85	74	17	9	185
		1528	8	0-2	0	0	148	85	34	34	301
		1625	9	0-2	0	0	79	284	148	79	590
		1644	10	0-1	0	0	85	176	28	40	329
		1550	11	5-7	0	0	170	165	17	40	392
		1610	11	0-2	0	23	96	153	23	23	318

TABLE 2. Water temperature (°C) and salinity measurements taken with a STD at each larval sampling station in Caraquet Bay in 1988.

DATE (1988)	JULIAN DATE	SITE	TEMP °C	SALINITY PSS
19-Jul	201	1	21.3	23.6
		2	20.8	24.8
		3	20.8	24.7
		4	20.7	25.1
		5	20.3	25.4
		6	20.4	25.3
		7	20.6	25.4
		8	20.2	25.6
		9	20.4	25.6
		10	20.8	25.8
		11	20.1	25.8
		12	18.1	26.4
20-Jul	202	1	21.4	18.7
		2	20.9	25
		3	20.8	24.9
		4	20.6	25.4
		5	20.4	25.2
		6	20.5	25.3
		7	20.4	25.1
		8	20.2	25.8
		9	20.6	25.7
		10	20.3	25.7
		11	19.7	26
21-Jul	203	1	22.6	18.4
		2	22.5	23.7
		3	22.3	22.3
		4	22	24
		5	20.8	25.6
		6	20.9	24.9
		7	21.4	24.9
		8	19.3	26.1
		9	20.6	25.7
		10	21.2	25.6
		11	19	26.2
		12	15.8	26.8
22-Jul	204	5	20.2	25.7
		6	20.6	25.5
		10	21.3	25.6
		11	19.2	26
24-Jul	206	1	23.4	12
		2	23.5	22.2
		3	23	24.6
		4	23.5	23.8
		5	22.4	25
		6	22.3	25.3
		7	22.3	25.4
		8	21.3	25.9
		10	21.9	25.9
		11	21.2	26

TABLE 2. Continued.

DATE (1988)	JULIAN DATE	SITE	TEMP °C	SALINITY PSS
25-Jul	207	1	22.8	21.2
		2	22.8	24.2
		3	22.3	24.7
		4	22.6	24.3
		5	20.5	26.1
		6	21.7	25.6
		7	22.3	25.4
		8	20.3	26.2
		9	21.2	26.1
		10	22	26.2
		11	18.2	26.8
		12	14.4	27.8
26-Jul	208	1	21.5	12
		2	22.2	19.6
		3	22.1	21.9
		4	22.1	23.1
		5	21.9	24.2
		6	21.4	24.7
		7	21.6	24.2
		8	20.4	25.9
		9	20.1	26.3
		10	20.9	26.2
		11	20.1	26.2
		12	16.5	27.2
27-Jul	209	1	20.2	11.1
		2	21.2	20.6
		3	20.9	24.9
		4	21.3	22.5
		5	20.8	25
		6	19.7	25.5
		7	20.5	25.1
		8	18.7	26.4
		9	18.8	26.4
		10	20.6	25.8
		11	18.5	25.6
28-Jul	210	1	20.4	12.5
		2	21.6	21.7
		3	21.2	22.8
		4	21.3	23.8
		5	20.6	25.3
		6	20.7	25.1
		7	20.3	25.3
		8	18.6	26.3
		9	20.6	25.9
		10	17.9	27
		11	17.2	26.8
		12	14.7	27.6

TABLE 2. Continued.

DATE (1988)	JULIAN DATE	SITE	TEMP °C	SALINITY PSS
29-Jul	211	1	21.8	15.4
		2	21.7	24.7
		3	22	23.7
		4	21.9	24.9
		5	21.3	25.5
		6	21.2	25.2
		7	20.5	26.4
		8	20	26.1
		9	19.9	26.7
		10	20.8	26.6
		11	18.8	26.1
		12	18.8	27.2
30-Jul	212	1	23.8	18
		2	23.9	24.4
		3	22.6	25.1
		4	23.8	24.8
		5	21.7	25.9
		6	22.5	25.7
		7	21.8	26.3
		8	21.7	26.1
		9	21.4	26.7
		10	22.2	26.7
		11	20.6	26.3
		12	19.6	27.1
31-Jul	213	1	22.9	24.8
		2	22.1	26
		3	21.3	26.6
		4	22.2	25.8
		5	21.2	26.8
		6	21.1	26.7
		7	21.6	26.4
		8	20.5	26.9
		9	21	26.7
		10	21.9	26.7
		11	19.5	27.1
01-Aug	214	1	22.1	23.6
		2	22.2	25.7
		3	21.7	26.3
		4	21.8	26.2
		5	21	26.9
		6	21.2	26.8
		7	21.8	26.4
		8	20.6	26.9
		9	21.5	26.6
		11	19.6	27.1
		12	19.7	27

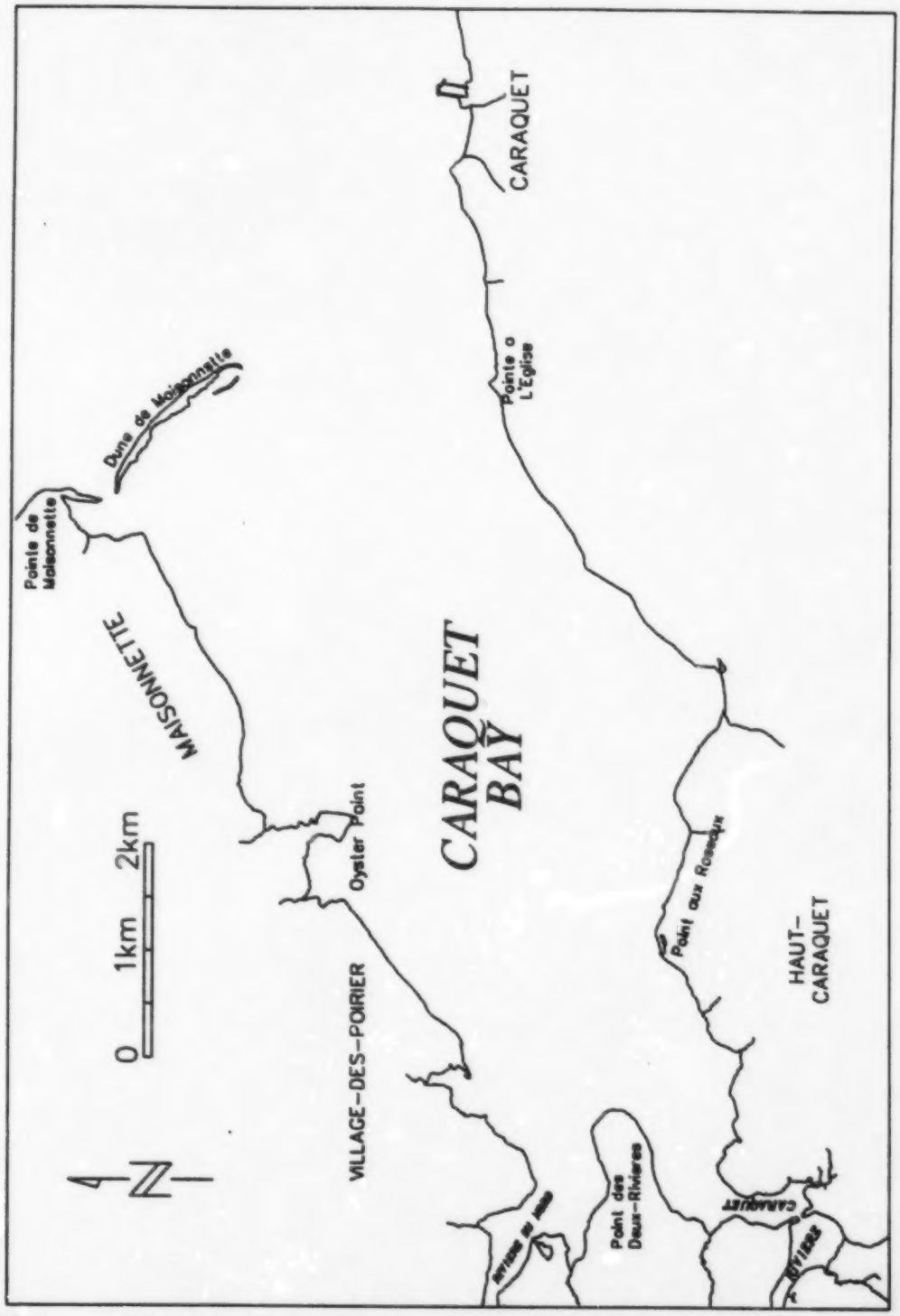


FIGURE 1. Map of Caraquet Bay, New Brunswick (47° 48' N, 65° 0' W) showing the main geographic landmarks and surrounding towns and villages.

FIGURE 2. Geographic location of Caraquet Bay (47° 48' N, 65° 0' W) in Atlantic Canada.

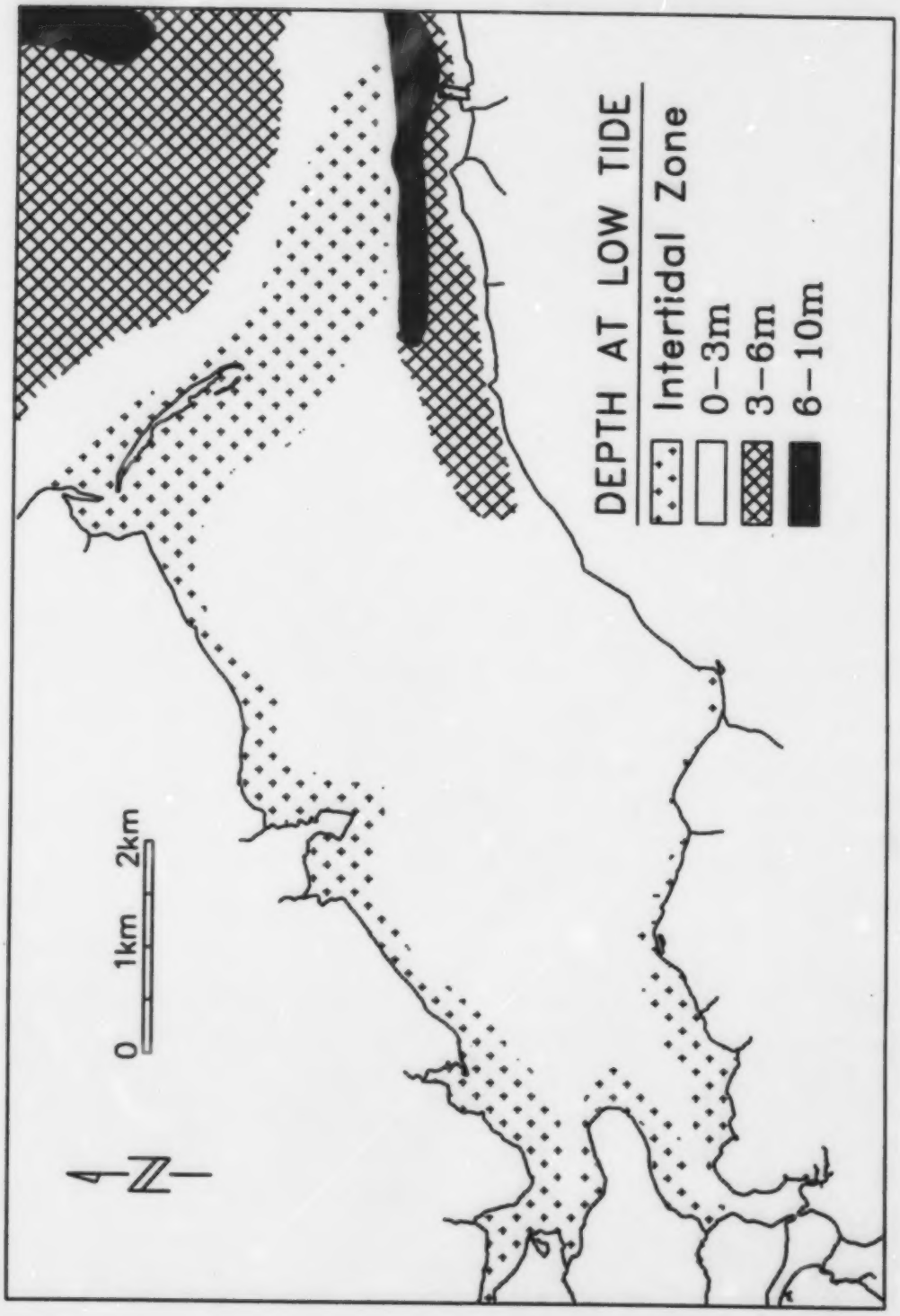


FIGURE 3. Extent of the intertidal zone and contoured water depths at low tide in Caraquet Bay.

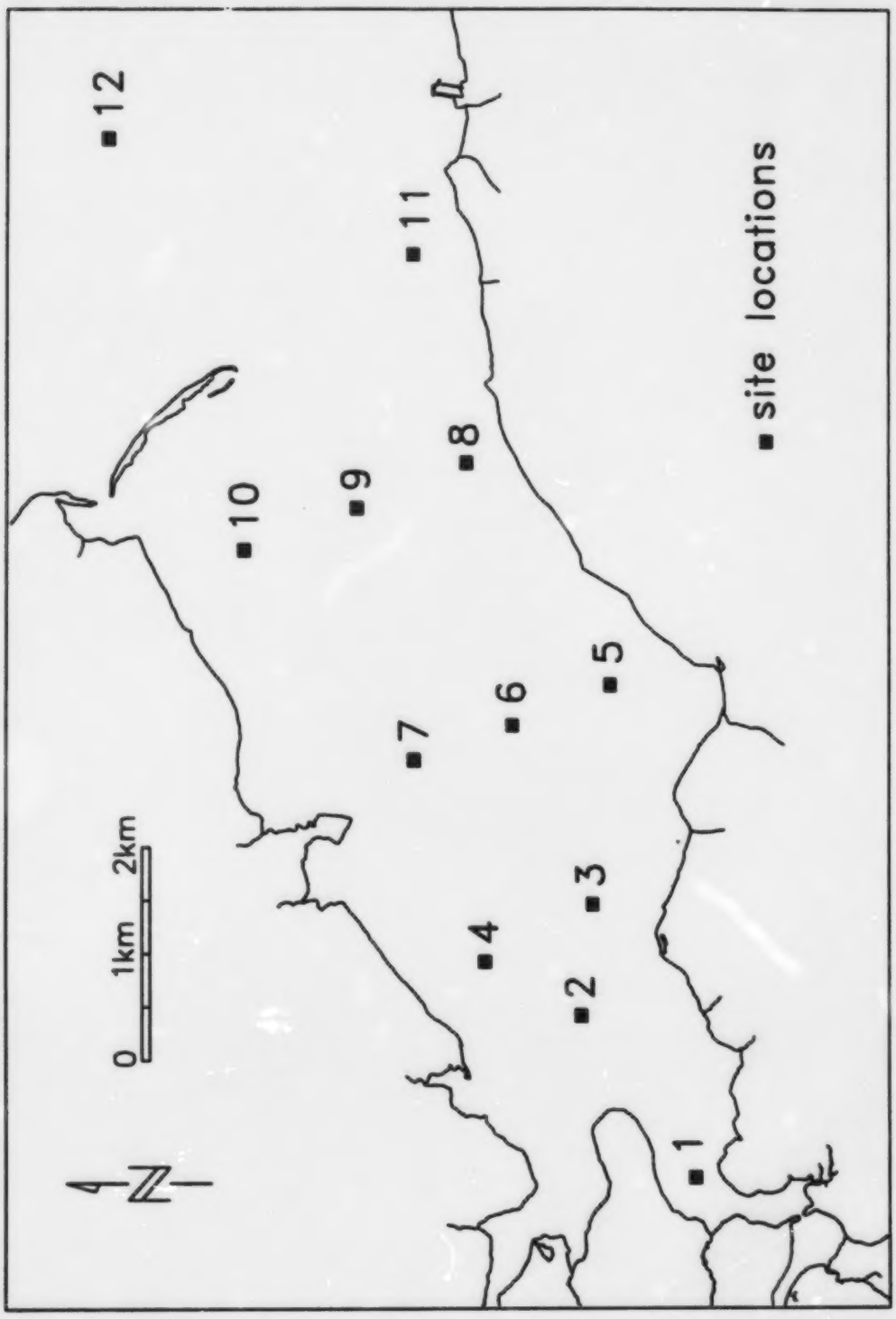


FIGURE 4. Location of oyster larvae sampling sites in Caraquet Bay.

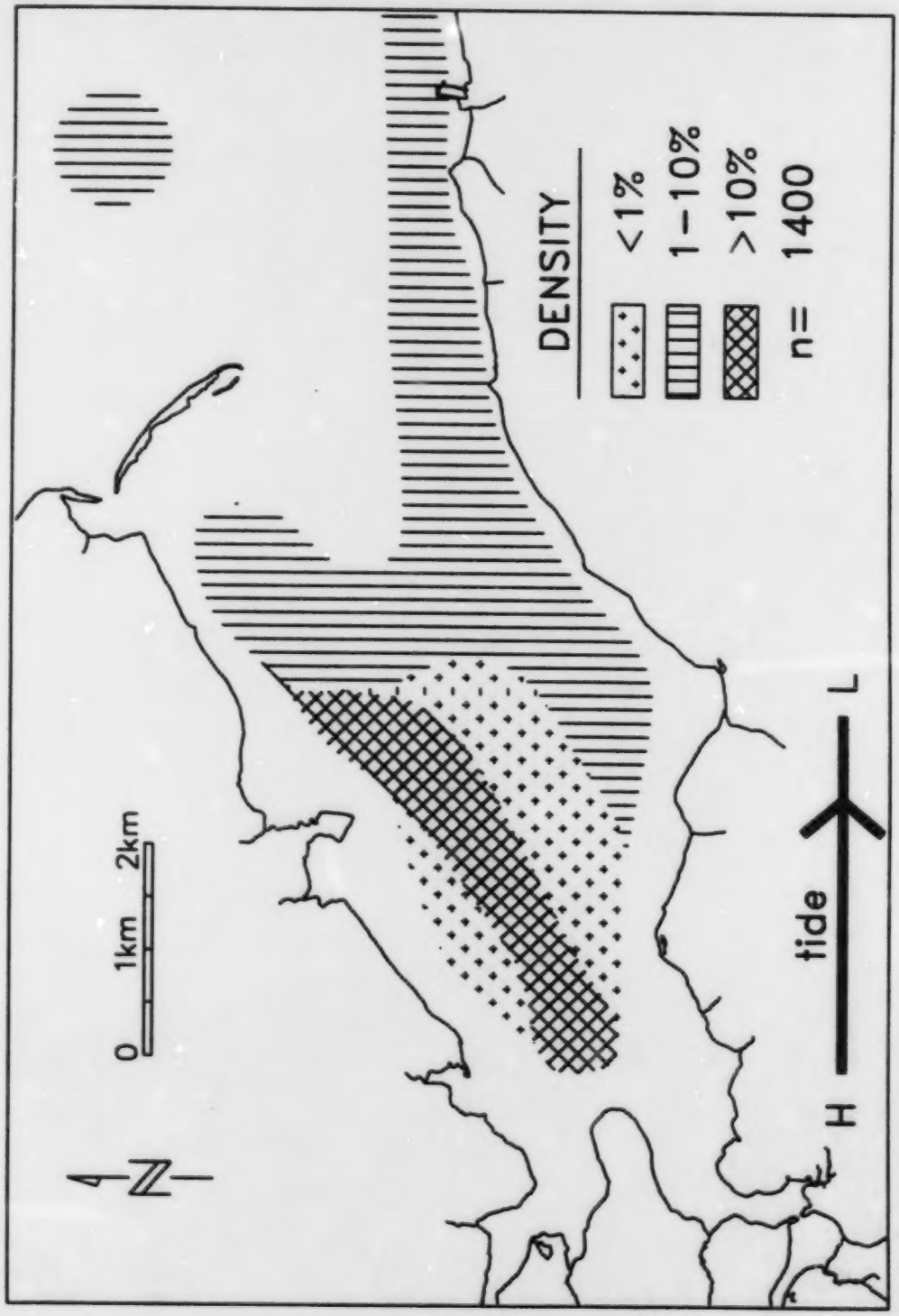


FIGURE 5. Density distribution of oyster larvae in Caraquet Bay on July 19, 1988 (Julian date 201). The state of the tide (falling to low) at the sampling midpoint and total number of larvae in all samples (n) are also indicated.

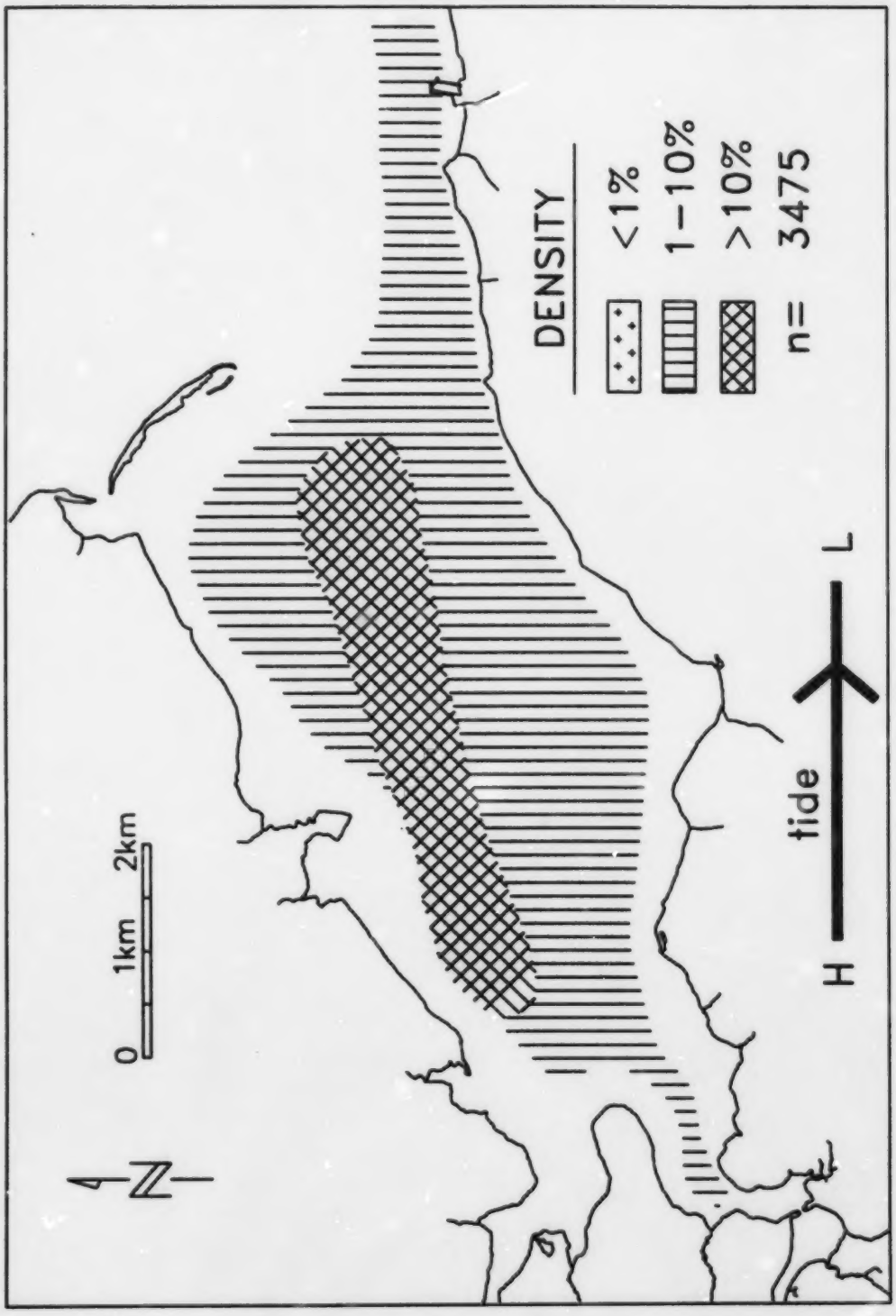


FIGURE 6. Density distribution of oyster larvae in Caraquet Bay on July 20, 1988 (Julian date 202). The state of the tide (falling to low) at the sampling midpoint and total number of larvae in all samples (n) are also indicated.

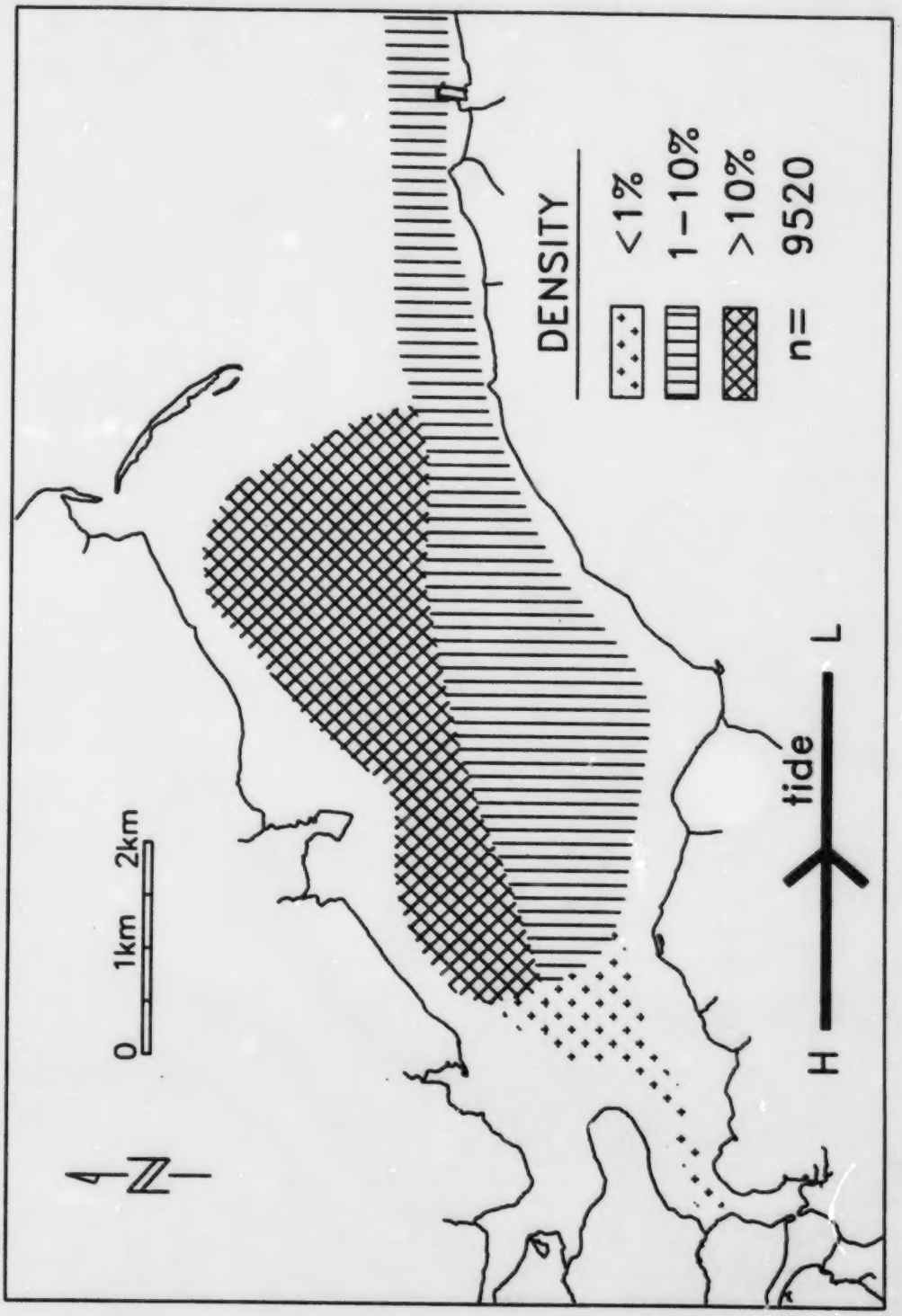


FIGURE 7. Density distribution of oyster larvae in Caraquet Bay on July 21, 1988 (Julian date 203). The state of the tide (midway) at the sampling midpoint and total number of larvae in all samples (n) are also indicated.

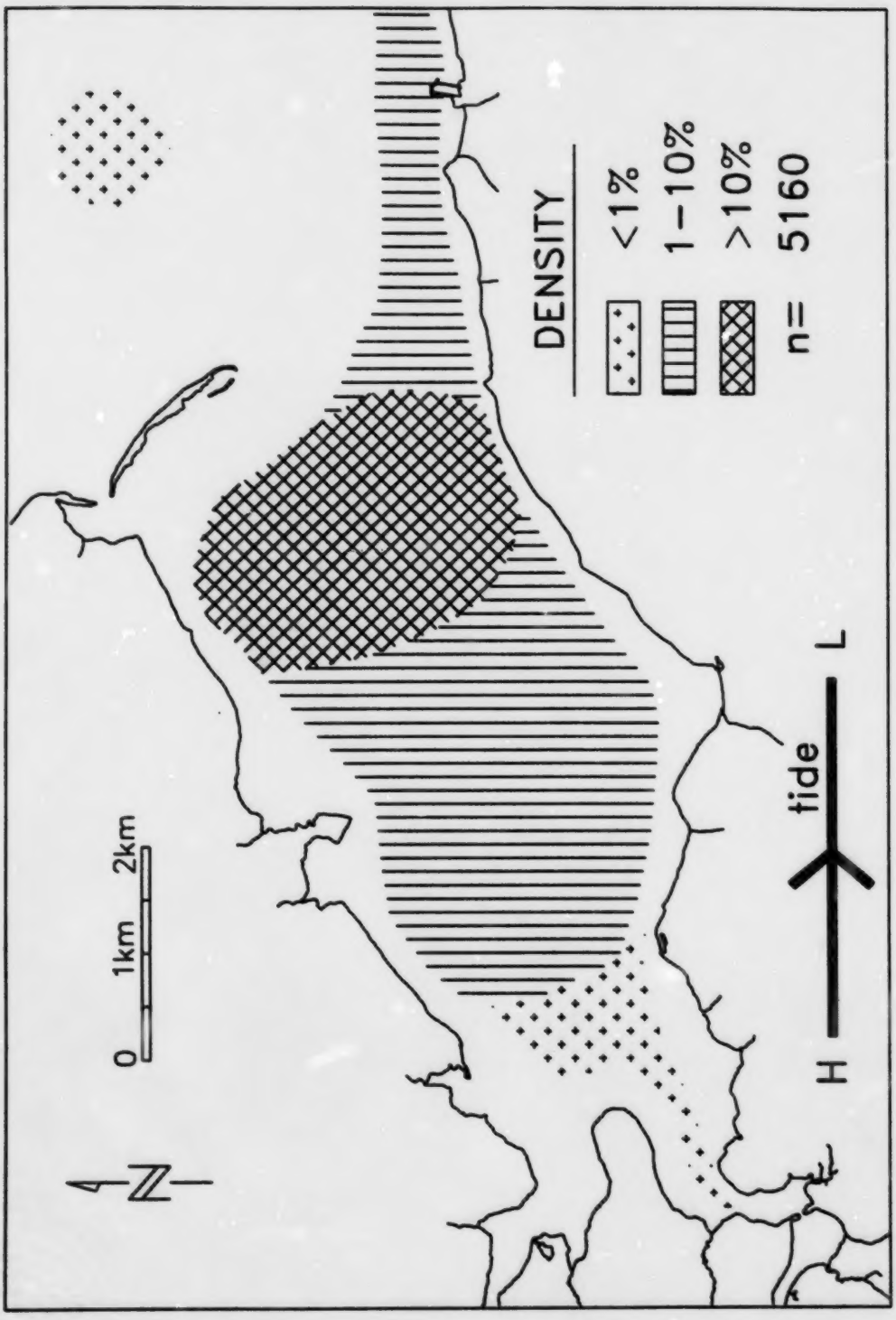


FIGURE 8. Density distribution of oyster larvae in Caraquet Bay on July 24, 1988 (Julian date 206). The state of the tide (midway) at the sampling midpoint and total number of larvae in all samples (n) are also indicated.

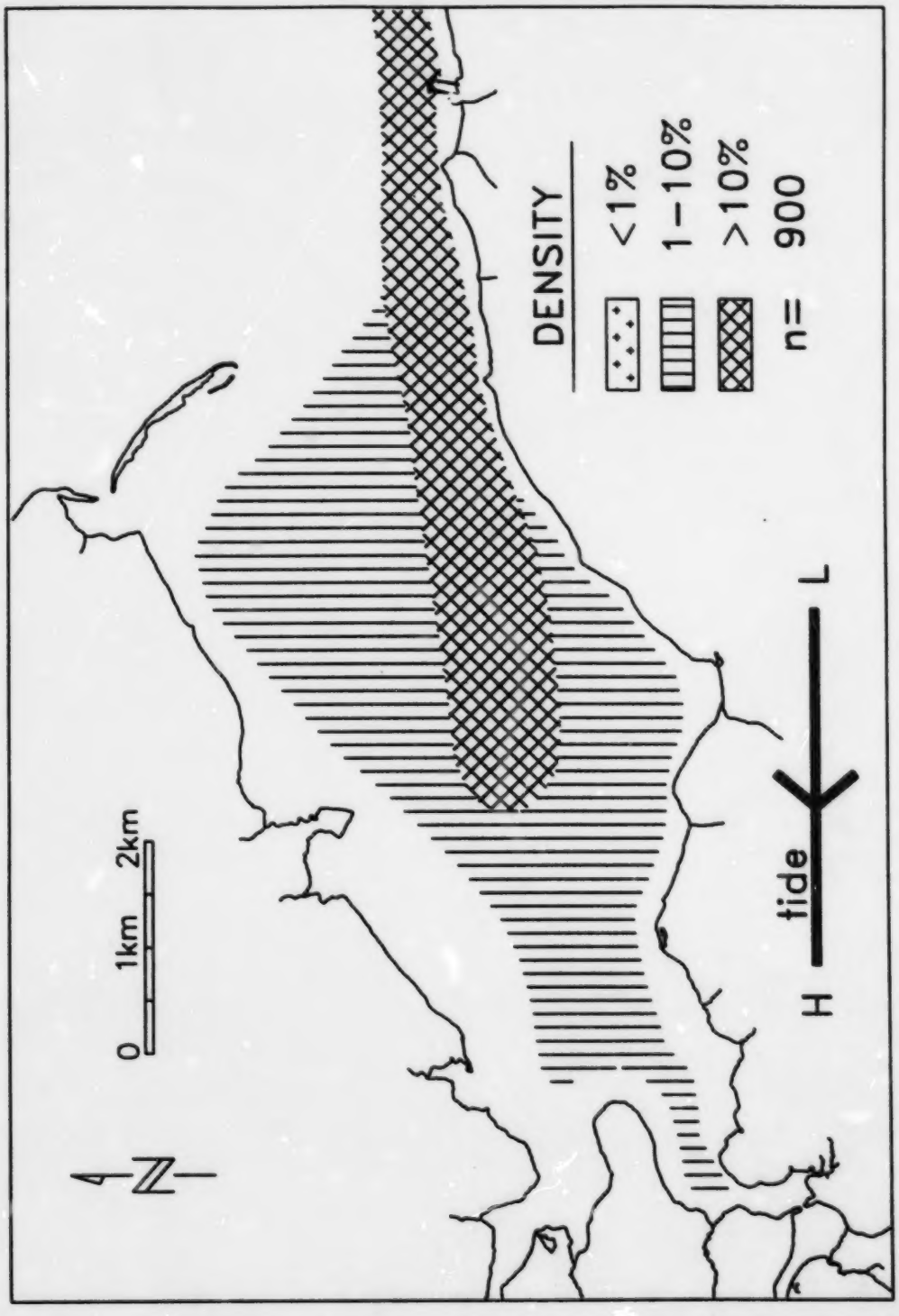


FIGURE 9. Density distribution of oyster larvae in Caraquet Bay on July 27, 1988 (Julian date 209). The state of the tide (midway, rising) at the sampling midpoint and total number of larvae in all samples (n) are also indicated.

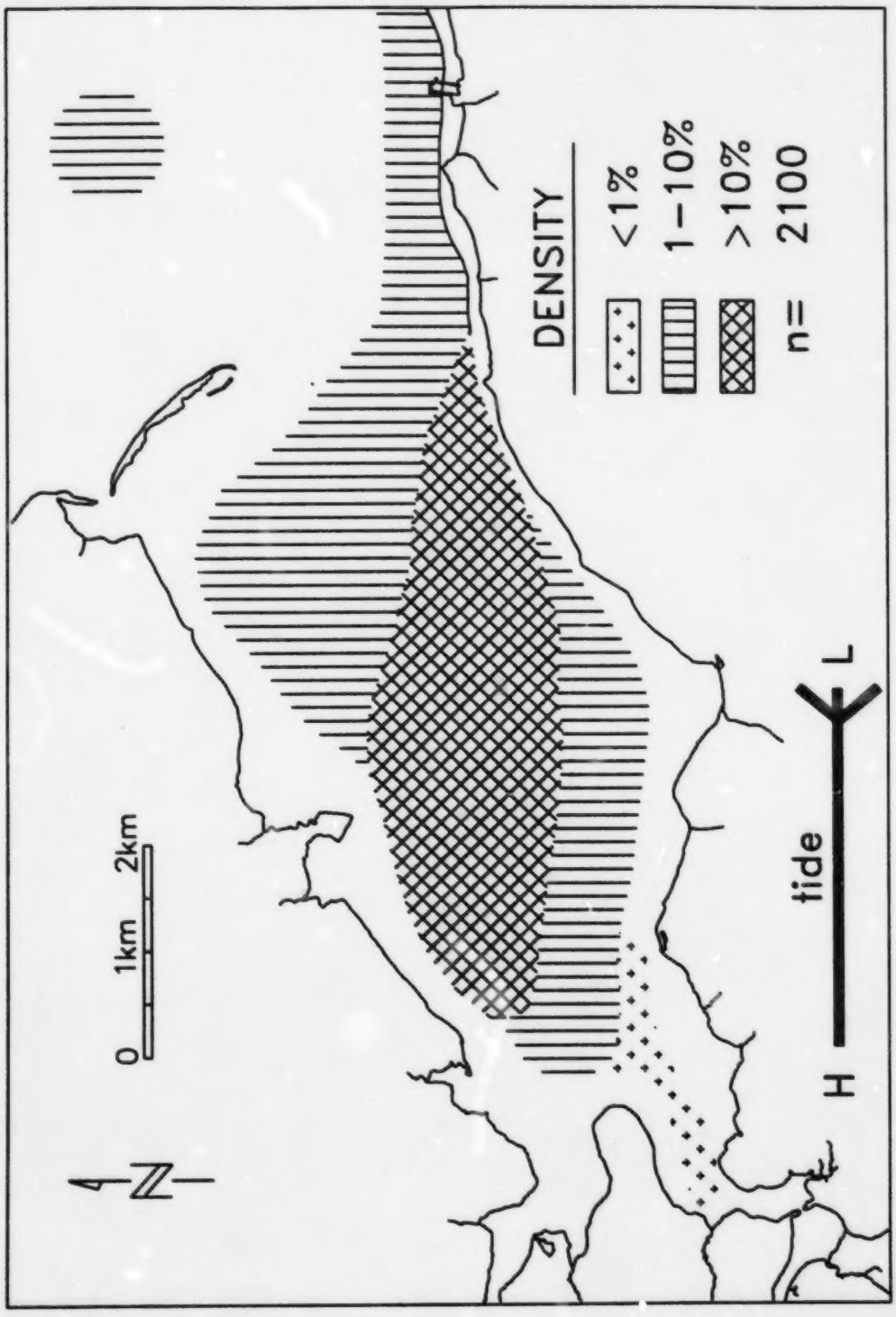


FIGURE 10. Density distribution of oyster larvae in Caraquet Bay on the morning of July 28, 1988 (Julian date 210). The state of the tide (low, rising) at the sampling midpoint and total number of larvae (n) are also indicated.

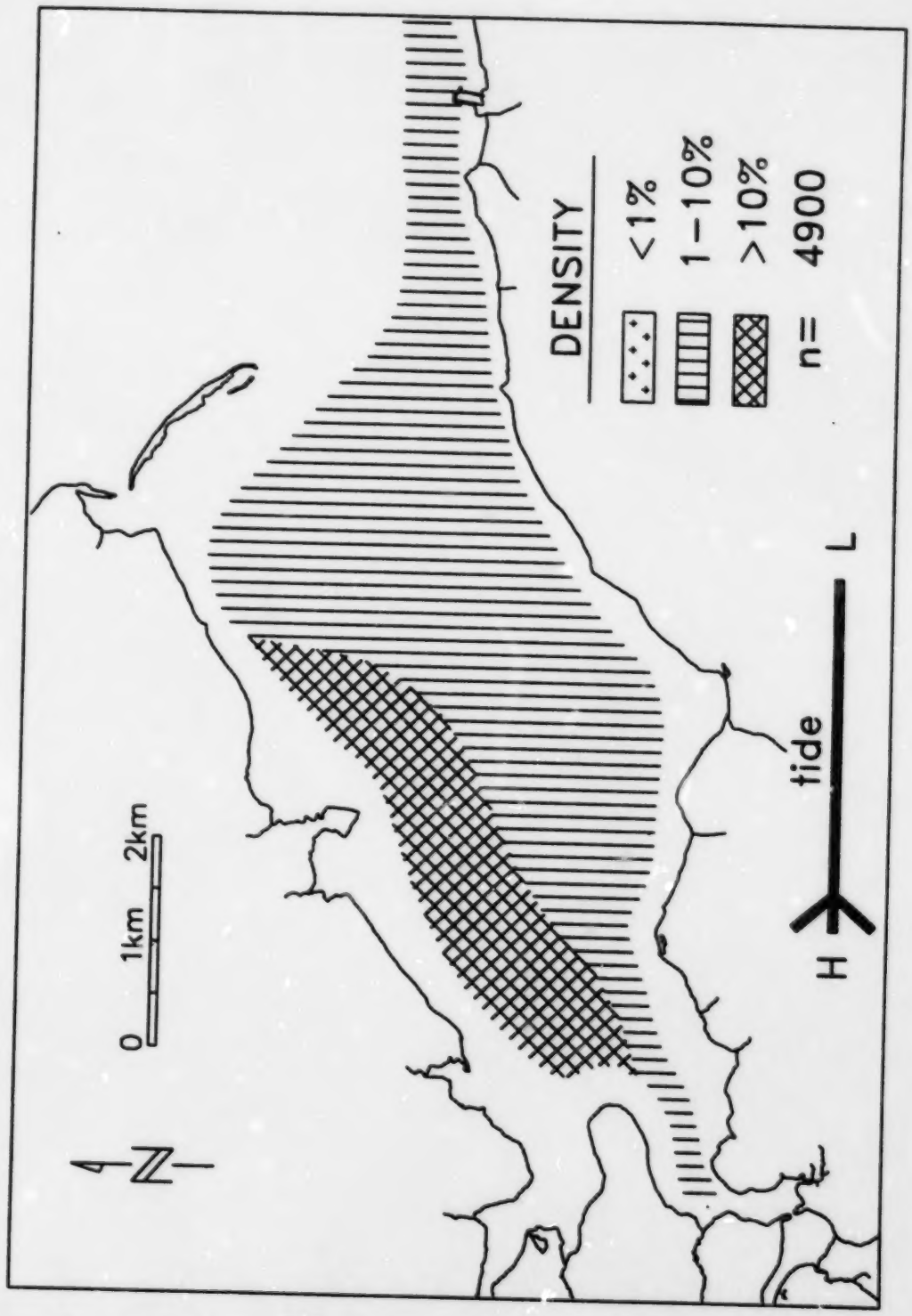


FIGURE 11. Density distribution of oyster larvae in Caraquet Bay on the afternoon of July 28, 1988 (Julian date 210). The state of the tide (high, falling) at the sampling midpoint and total number of larvae (n) are also indicated.

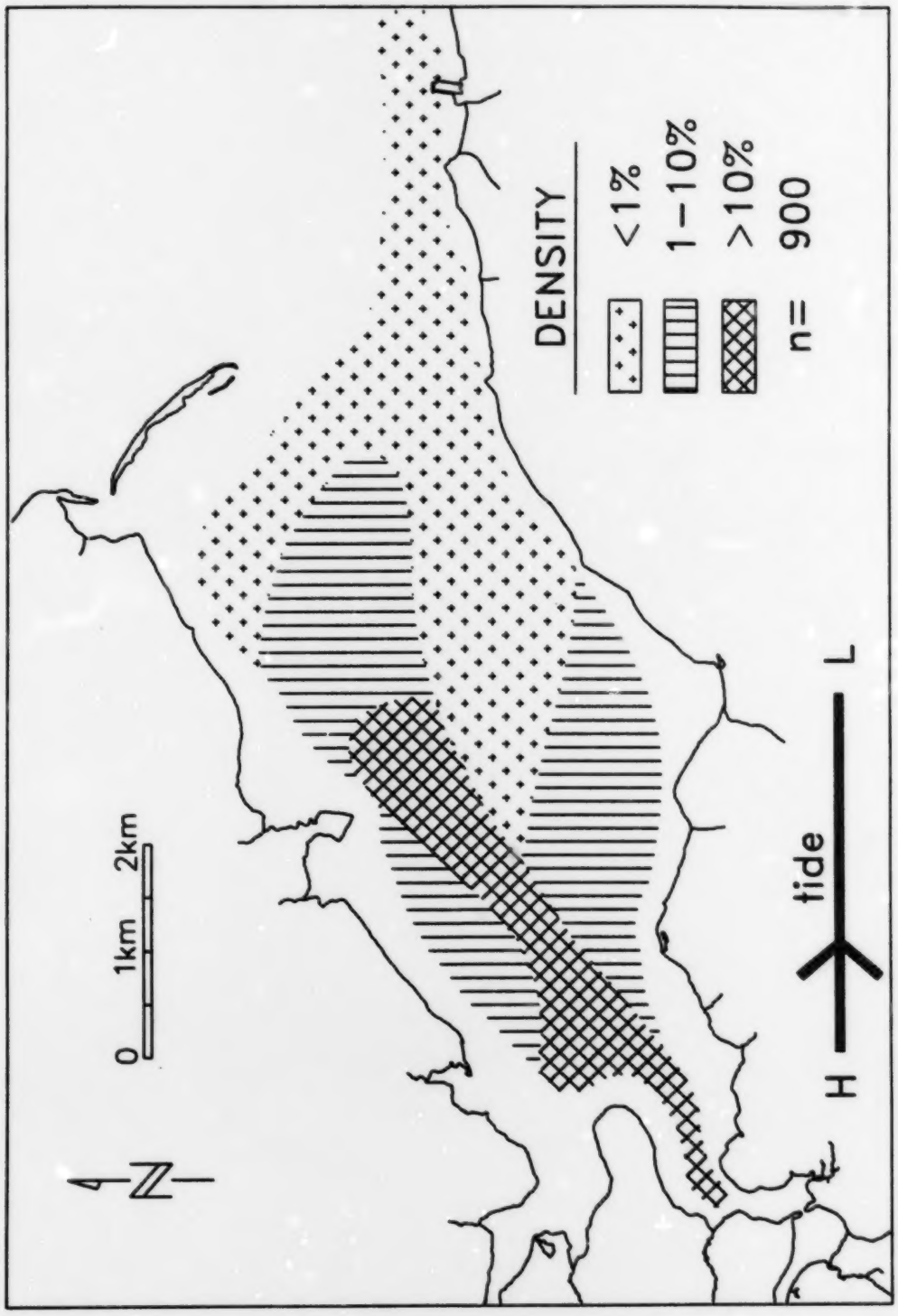


FIGURE 12. Density distribution of oyster larvae in Caraquet Bay on the morning of July 31, 1988 (Julian date 213). The state of the tide (falling to midway) at the sampling midpoint and total number of larvae (n) are also shown.

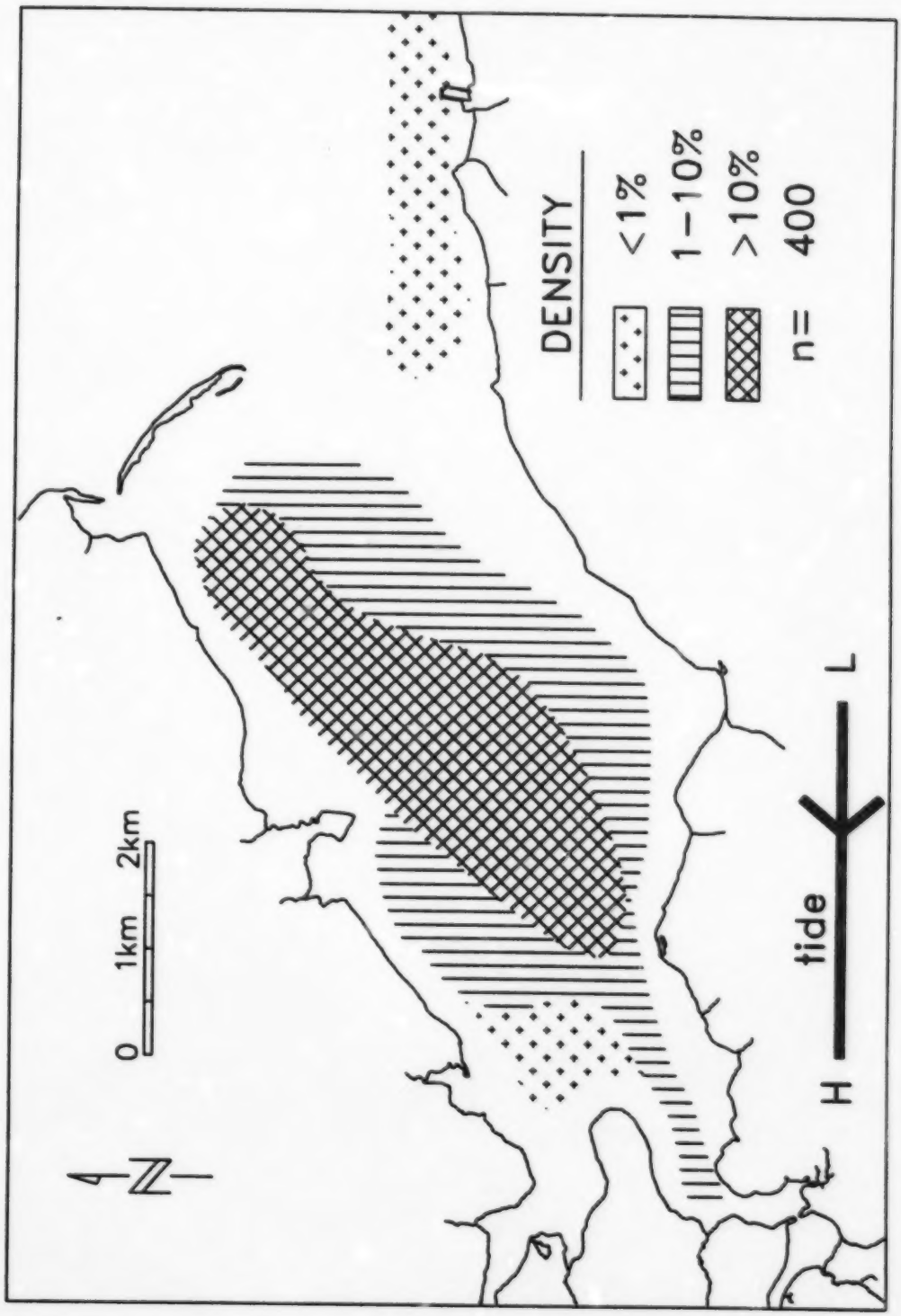


FIGURE 13. Density distribution of oyster larvae in Caraquet Bay on the afternoon of July 31, 1988 (Julian date 213). The state of the tide (rising to midway) at the sampling midpoint and total number of larvae (n) are also shown.

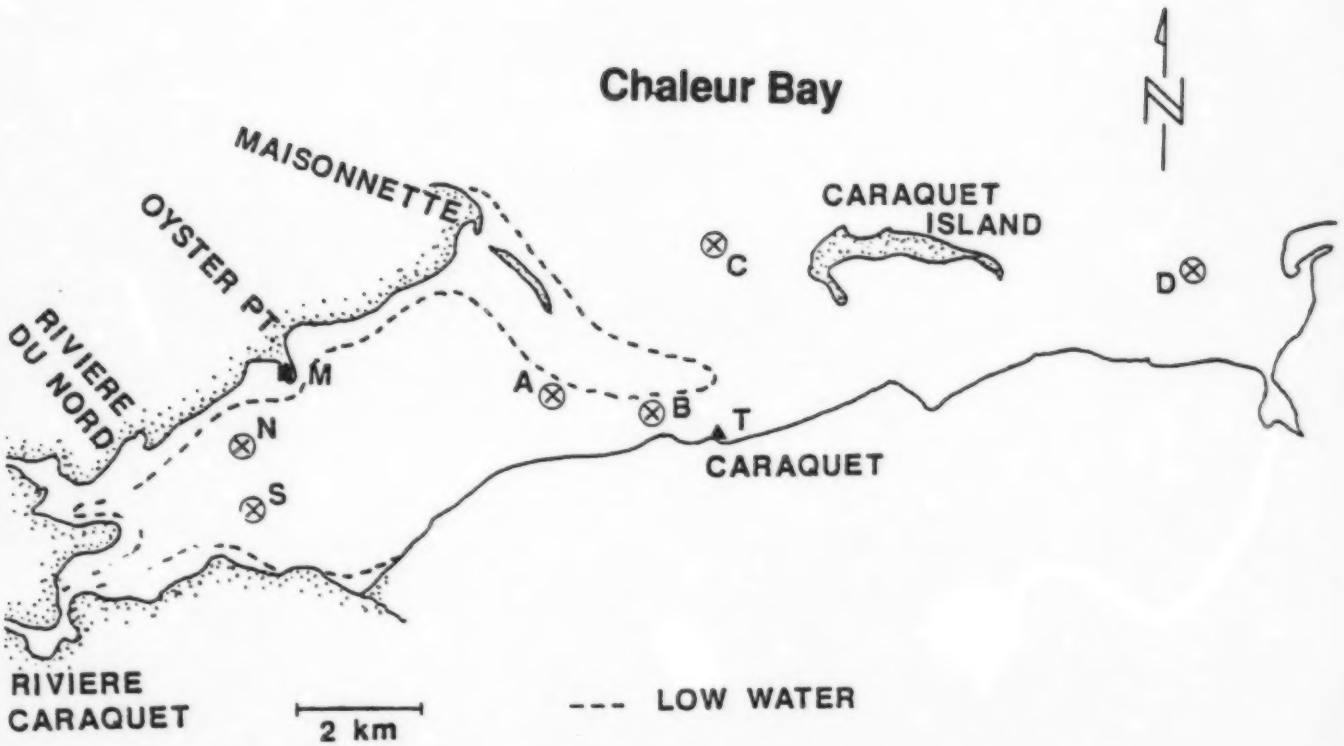


FIGURE 14. Location of the oceanographic sampling stations in Caraquet Bay (47° 48' N, 65° 0' W). Current meter (A, B, C, D, N and S), meterological station (M) and tide gauge (T) locations are indicated. (See text for details.)

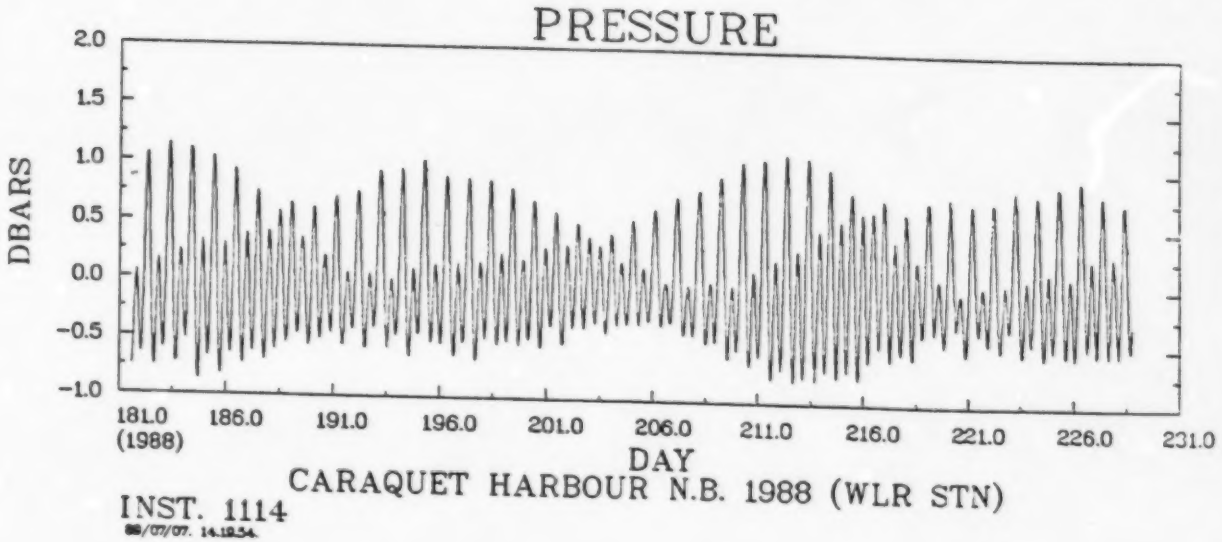
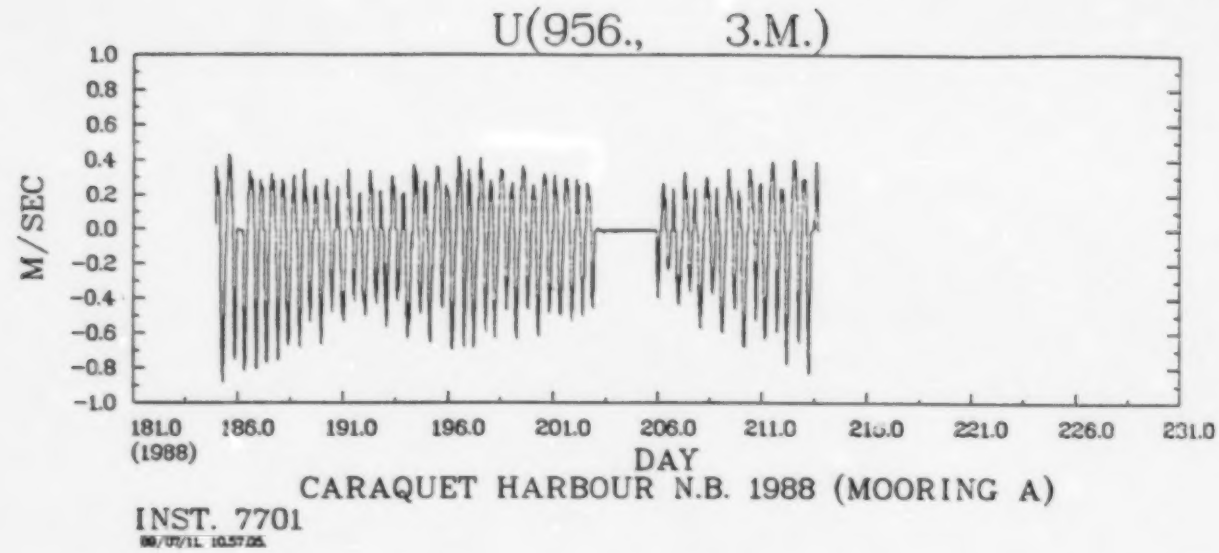


FIGURE 15. Tide gauge pressure data (1 decibars ≈ 1 metre) collected at the Caraquet Harbour wharf in 1988. All days are Julian days.



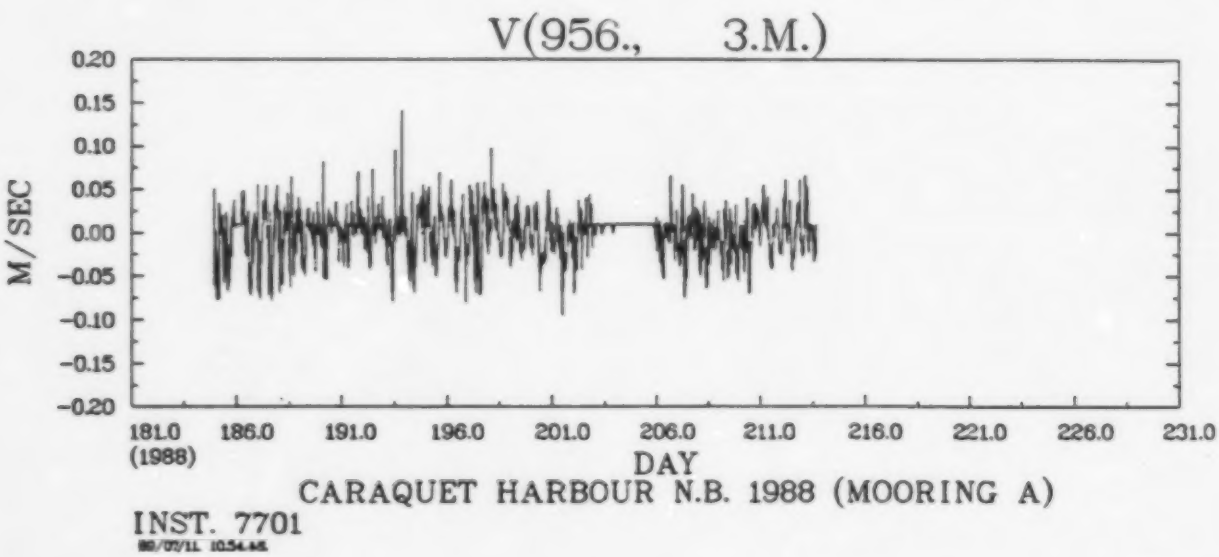
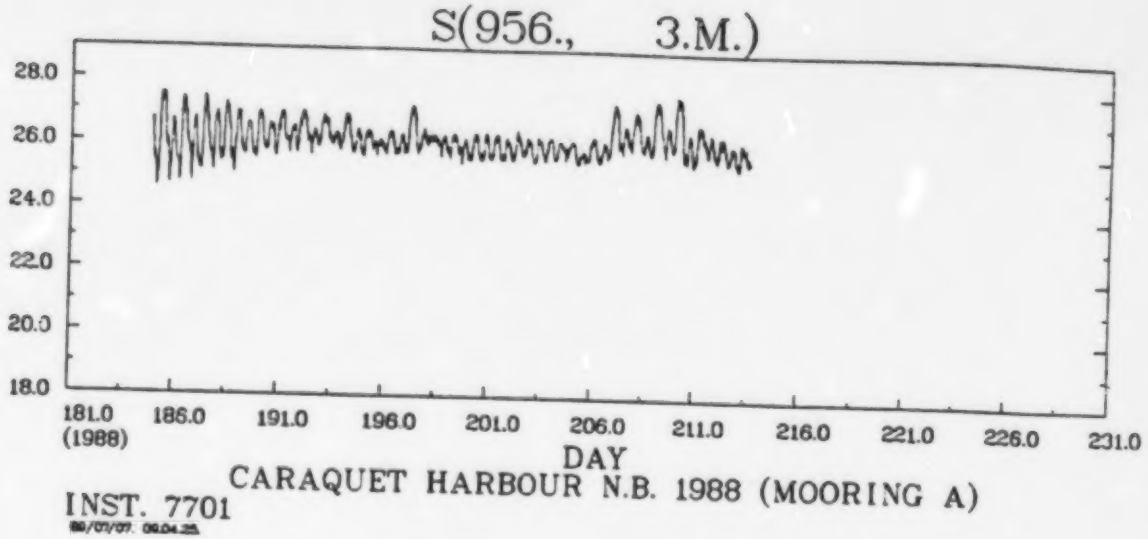


FIGURE 16. East (U) and north (V) water velocities at 3 m depth at mooring A in Caraquet Bay in 1988. All days are Julian days.



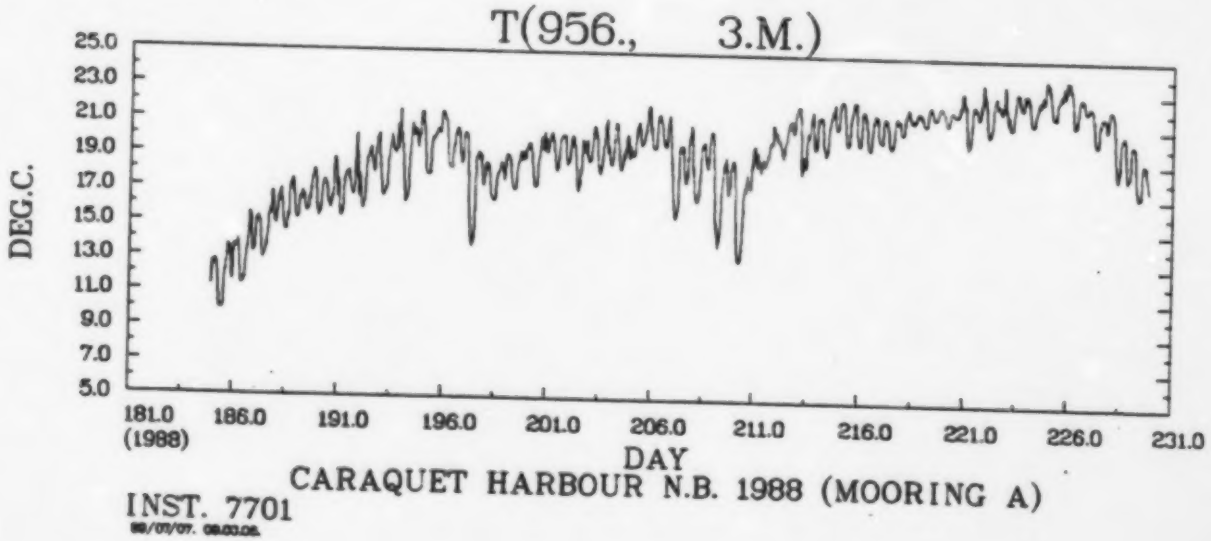
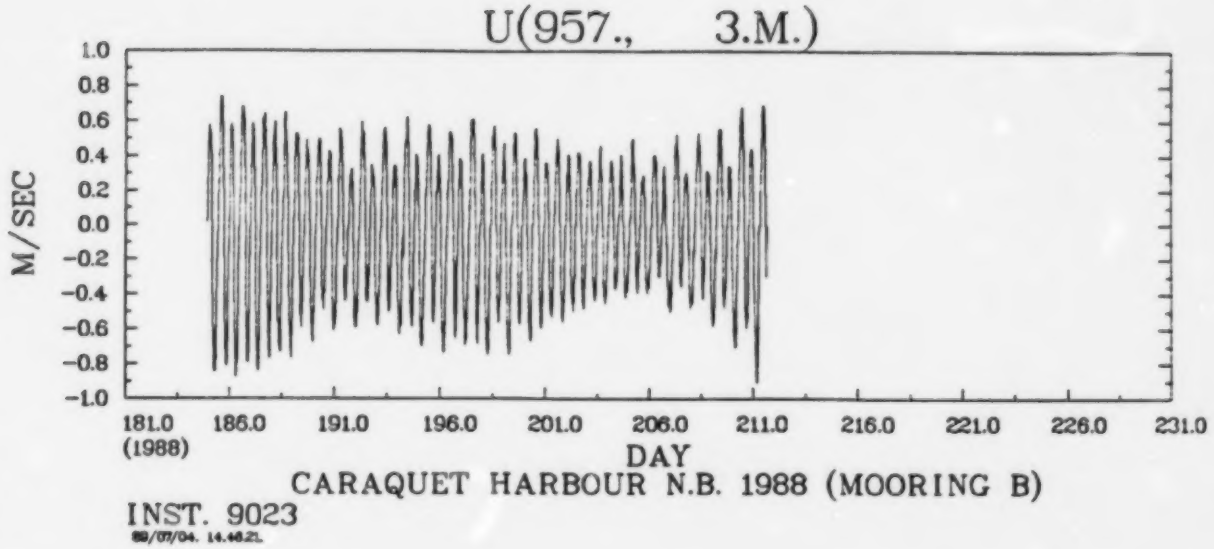


FIGURE 17. Salinity (S) and temperature (T) (°C) at 3 m depth at mooring A in Caraquet Bay in 1988. All days are Julian days.



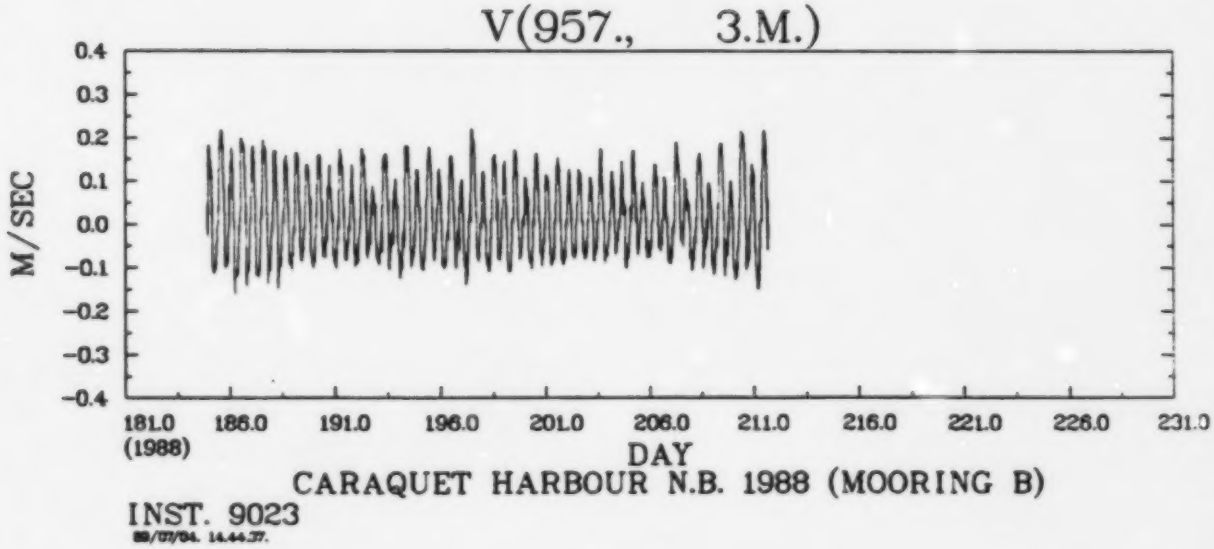
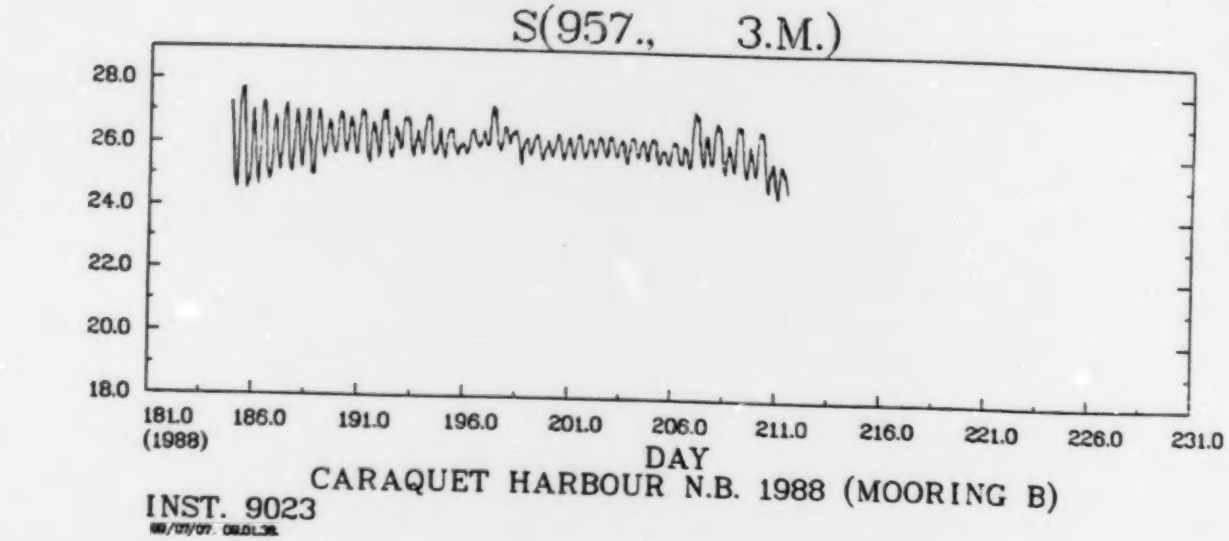


FIGURE 18. East (U) and north (V) water velocities at 3 m depth at mooring B in Caraquet Bay in 1988. All days are Julian days.



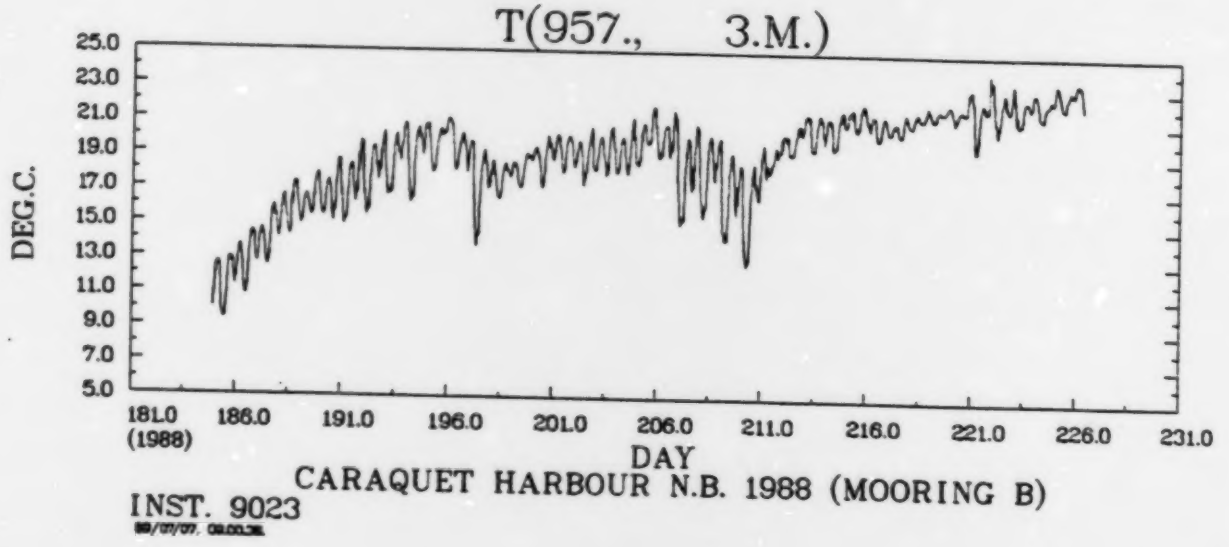
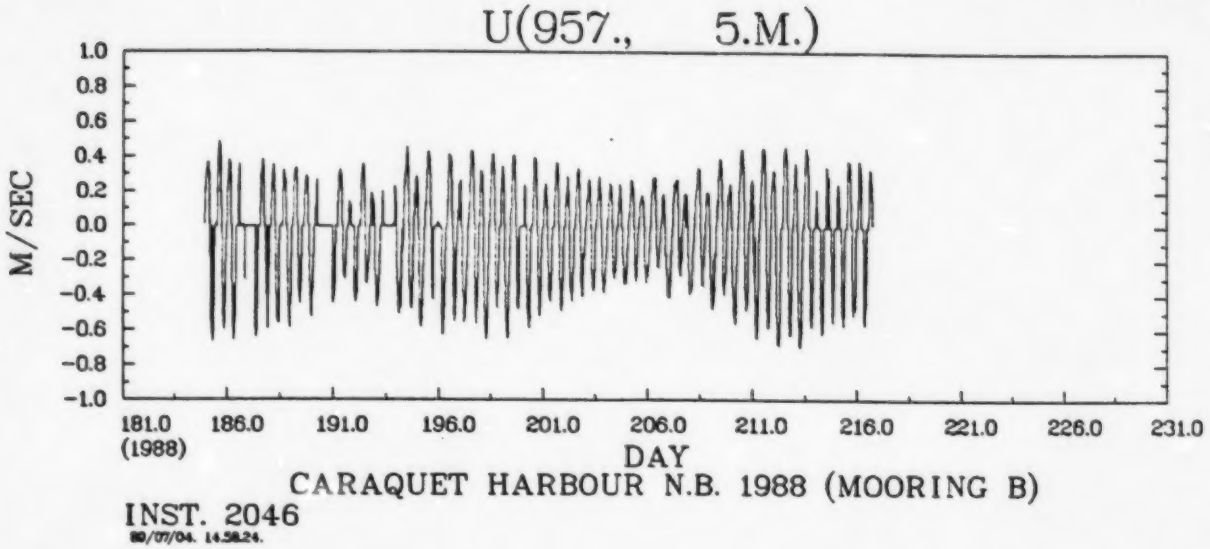


FIGURE 19. Salinity (S) and temperature (T) (°C) at 3 m depth at mooring B in Caraquet Bay in 1988. All days are Julian days.



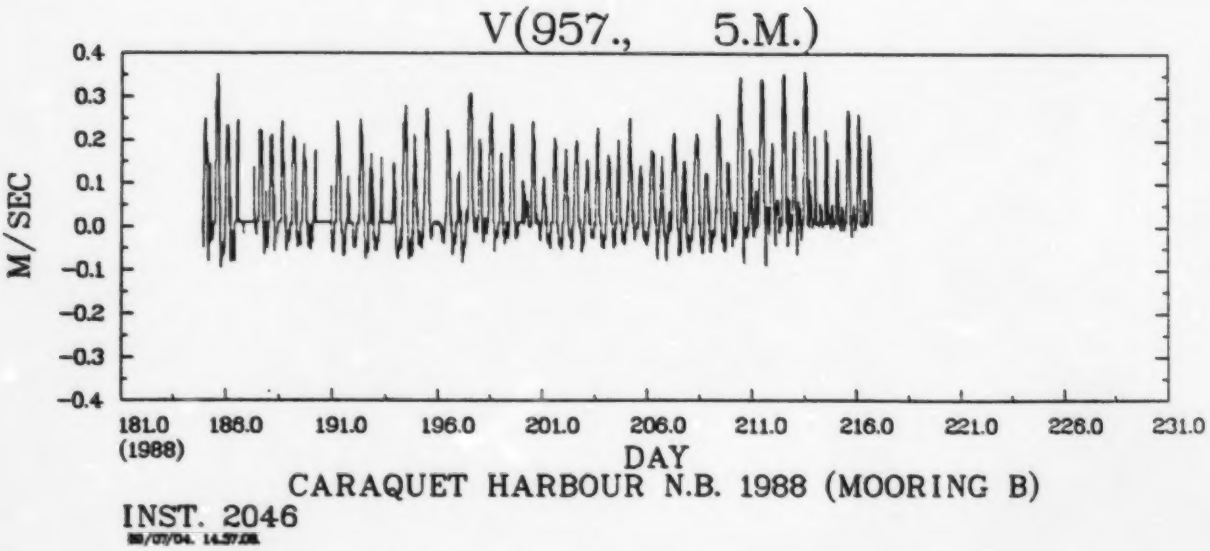
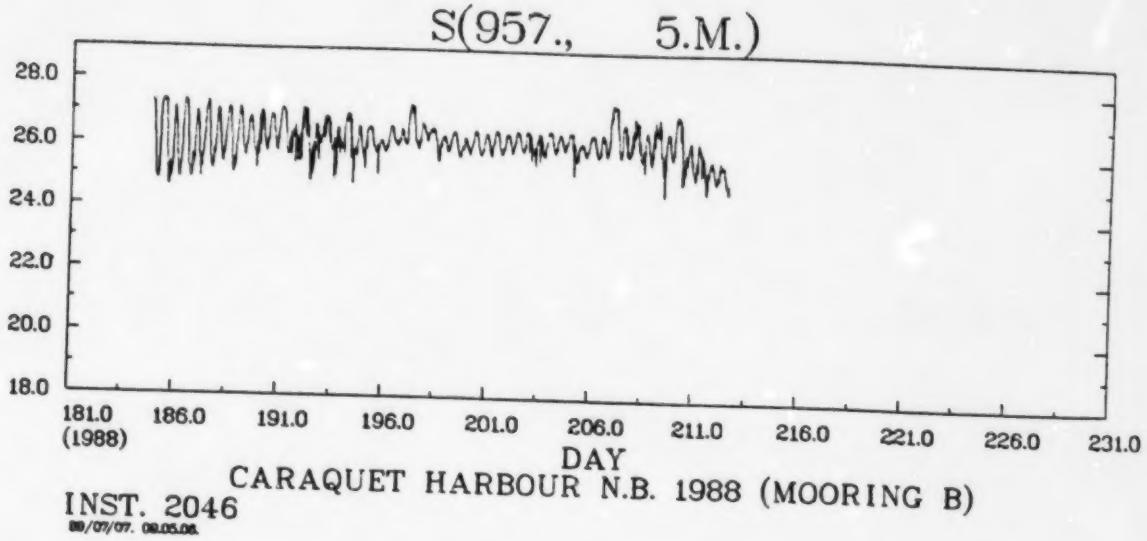


FIGURE 20. East (U) and north (V) water velocities at 5 m depth at mooring B in Caraquet Bay in 1988. All days are Julian days.



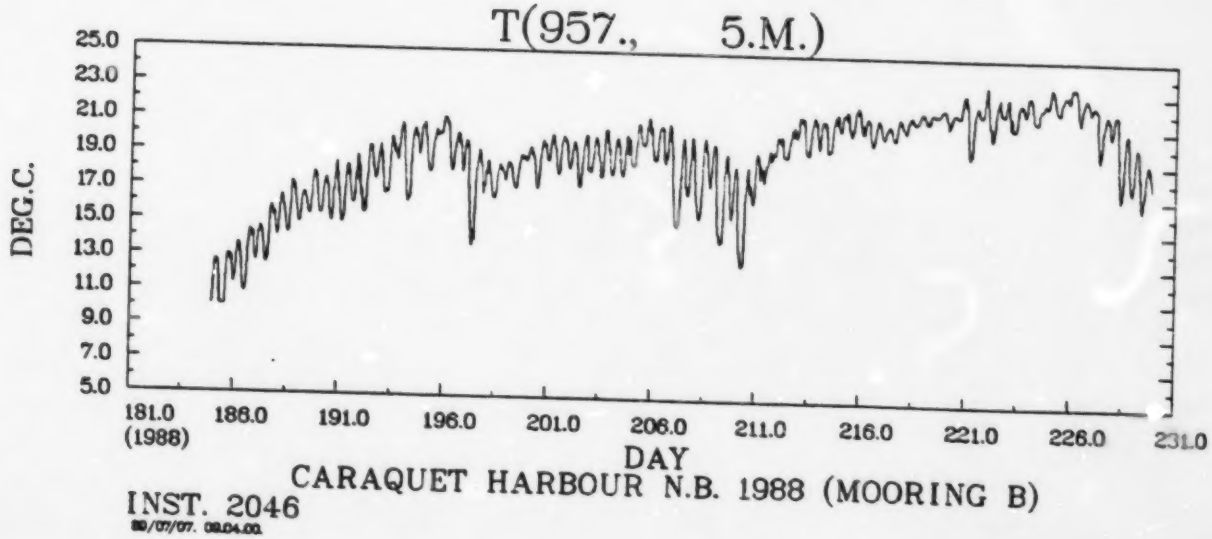
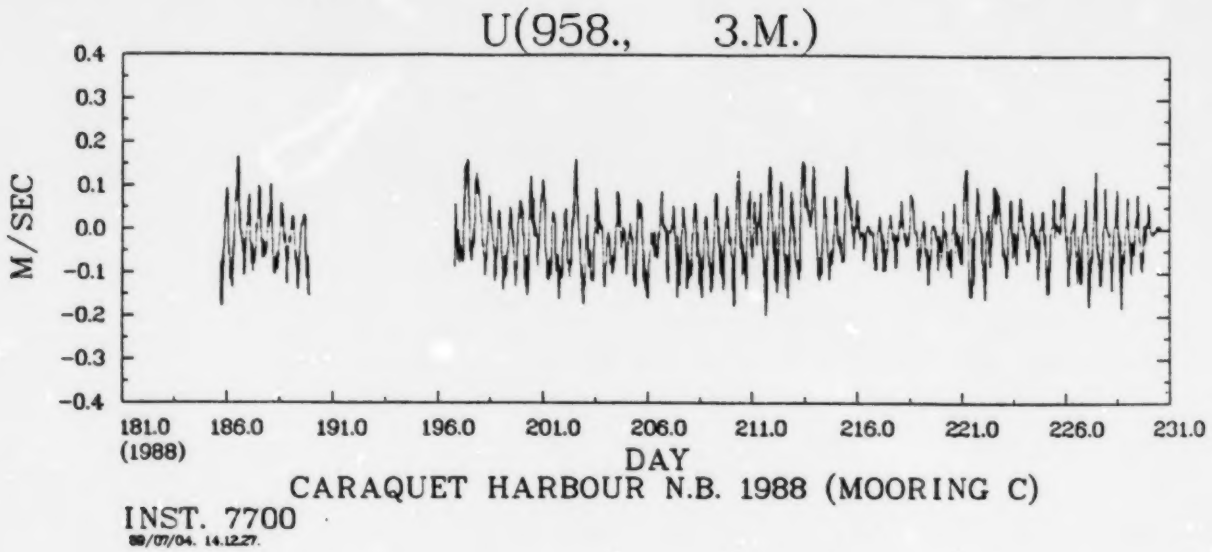


FIGURE 21. **Salinity (S) and temperature (T) (°C) at 5 m depth at mooring B in Caraquet Bay in 1988. All days are Julian days.**



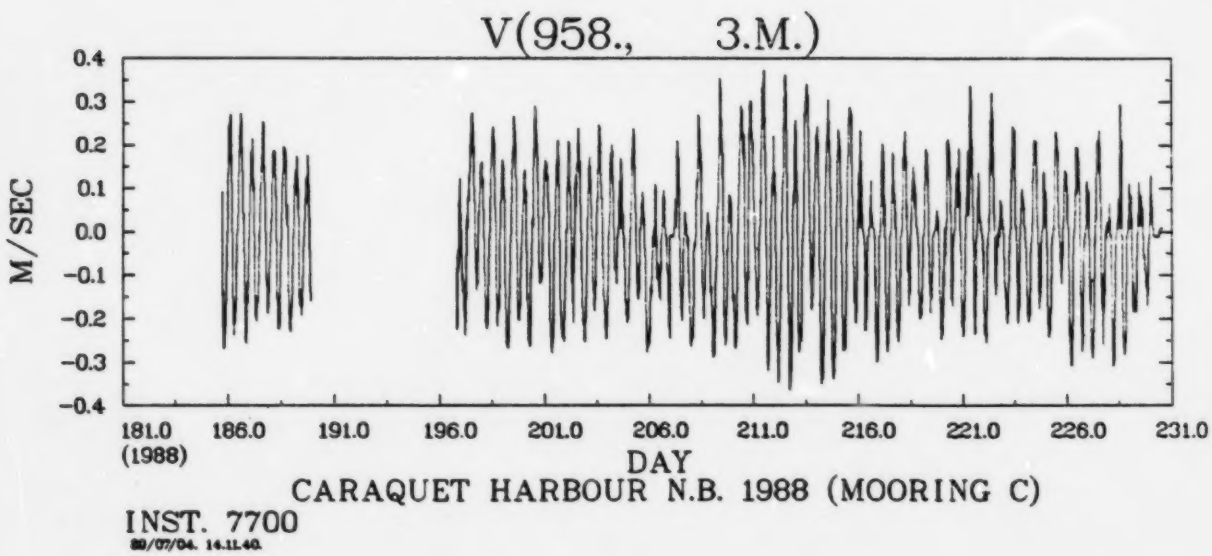
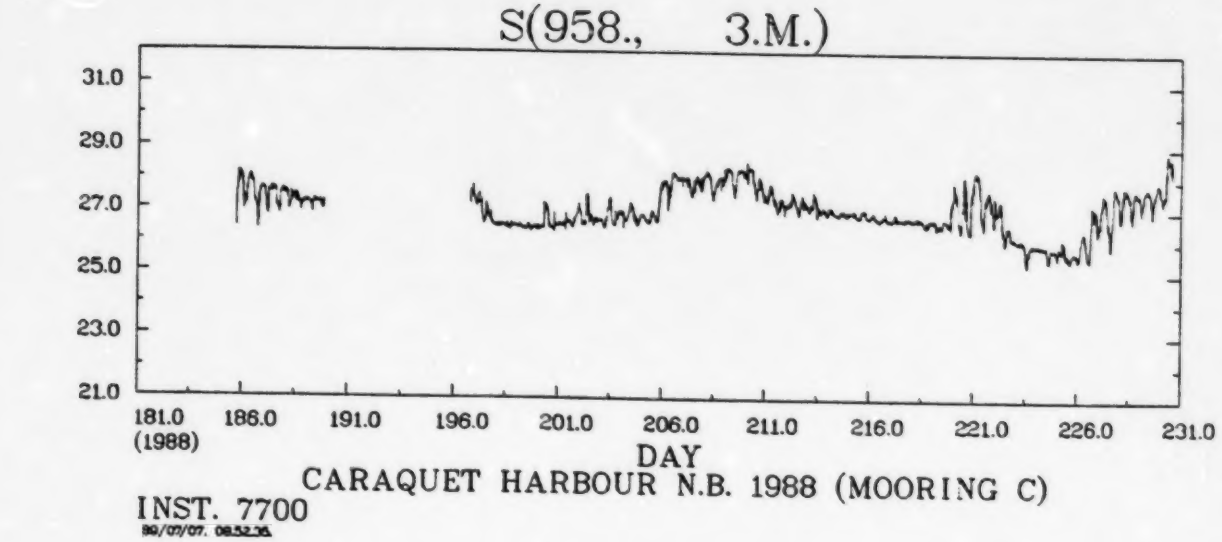


FIGURE 22. East (U) and north (V) water velocities at 3 m depth at mooring C in Caraquet Bay in 1988. After being recovered accidentally, this mooring was redeployed 300 m to the northeast of the original position. The position on the location map is that of the second position. All days are Julian days.



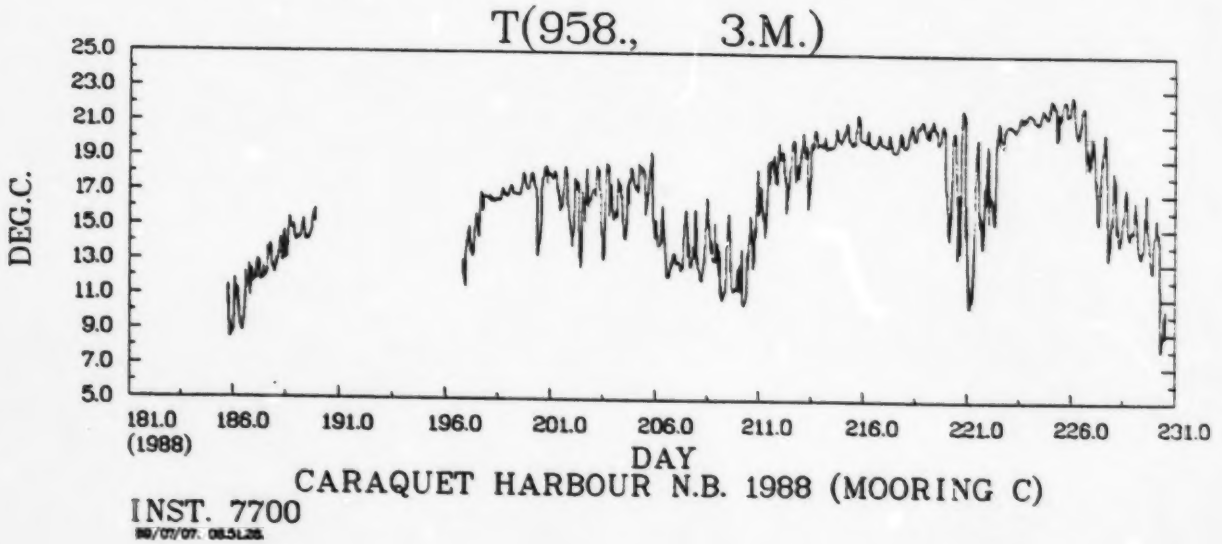
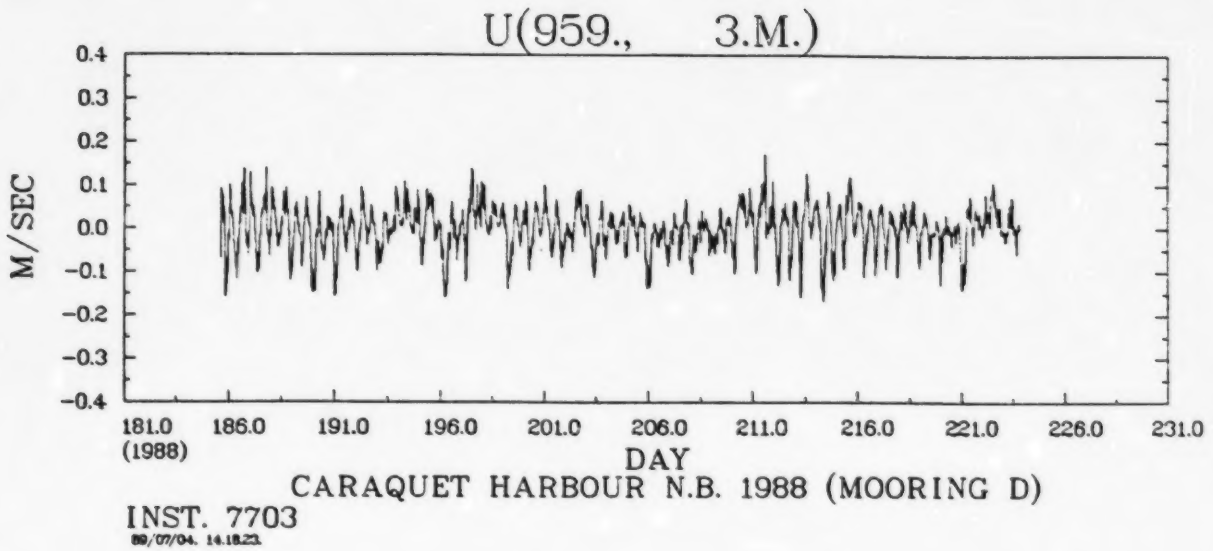


FIGURE 23. Salinity (S) and temperature (T) (°C) at 3 m depth at mooring C in Caraquet Bay in 1988. All days are Julian days.



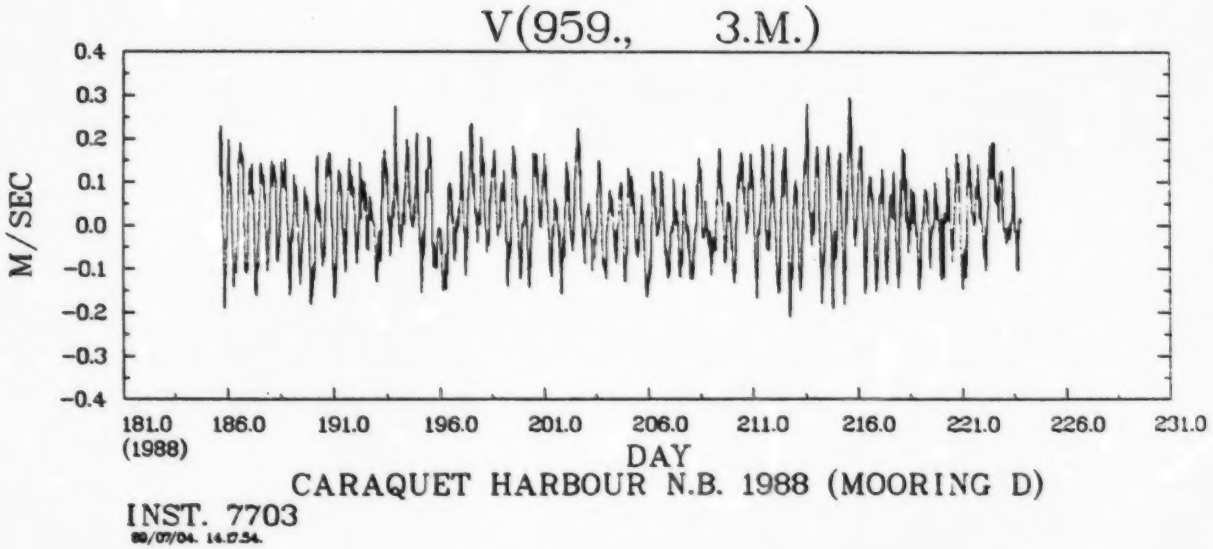


FIGURE 24. East (U) and north (V) water velocities at 3 m depth at mooring D in Caraquet Bay in 1988. All days are Julian days.

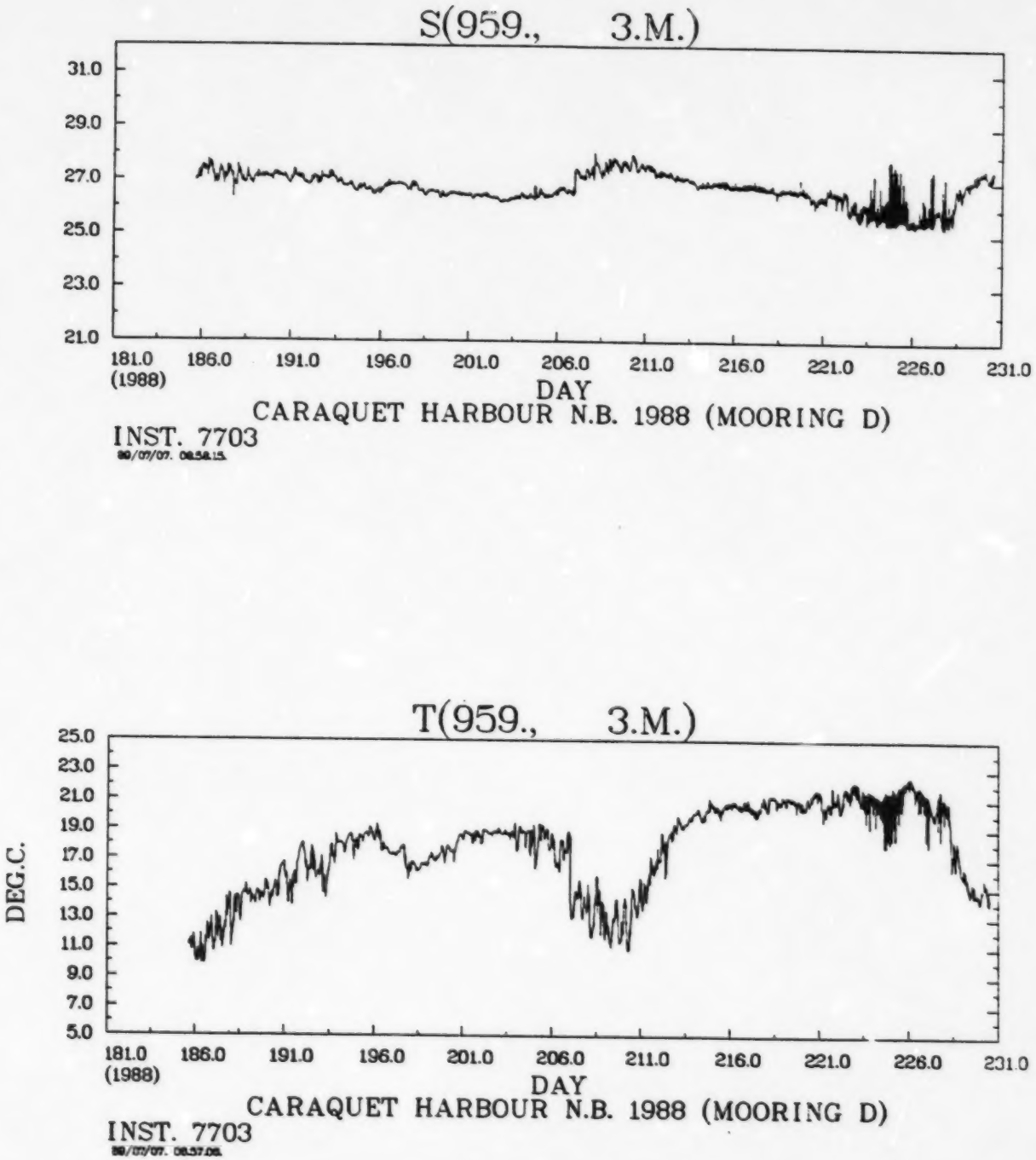
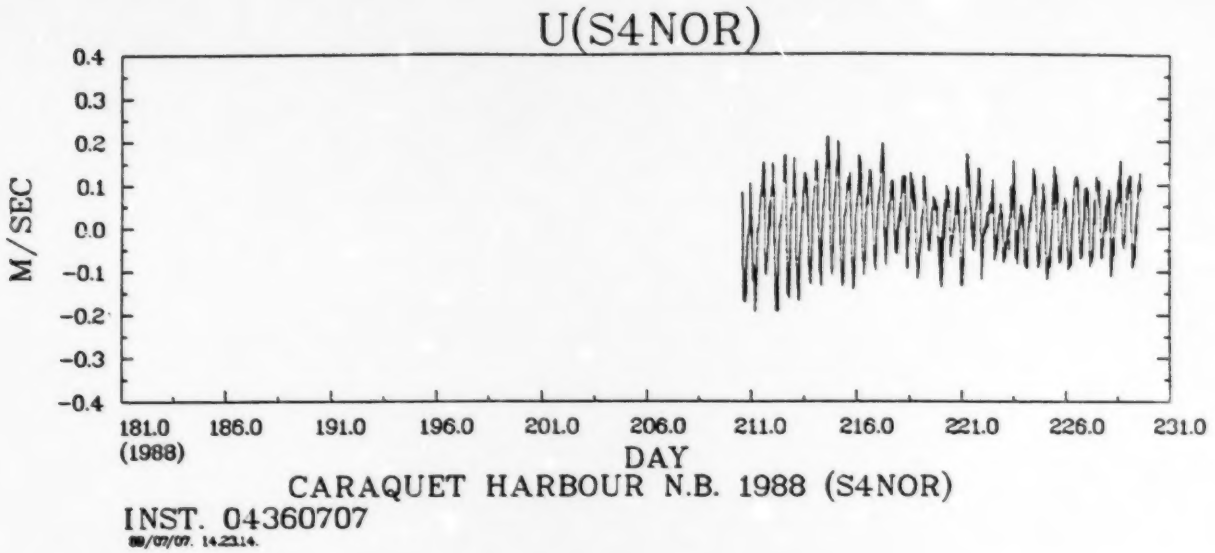


FIGURE 25. Salinity (S) and temperature (T) (°C) at 3 m depth at mooring D in Caraquet Bay in 1988. All days are Julian days.



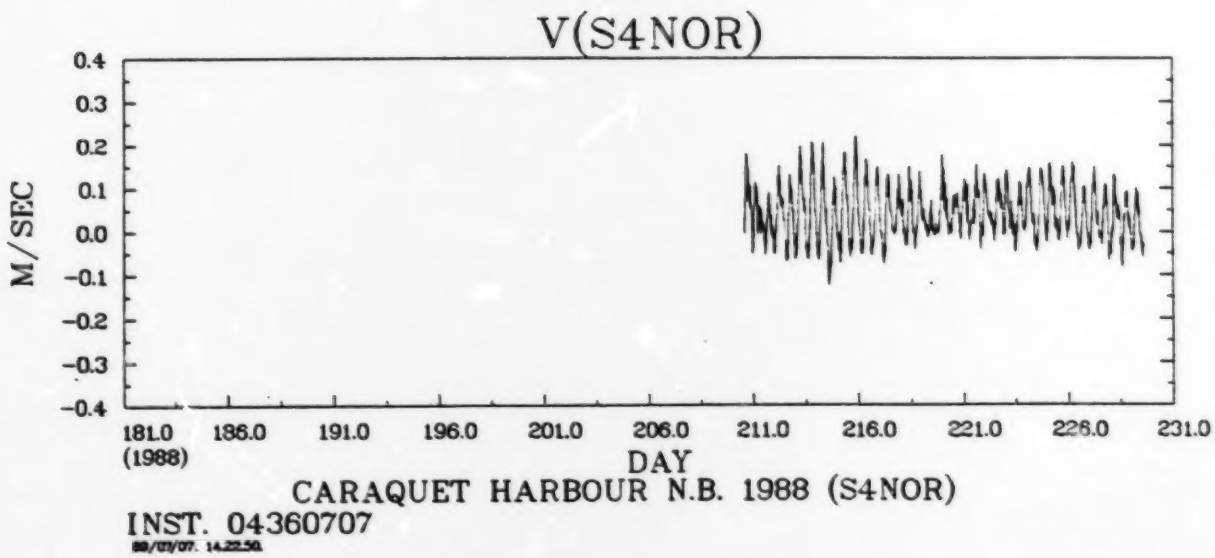
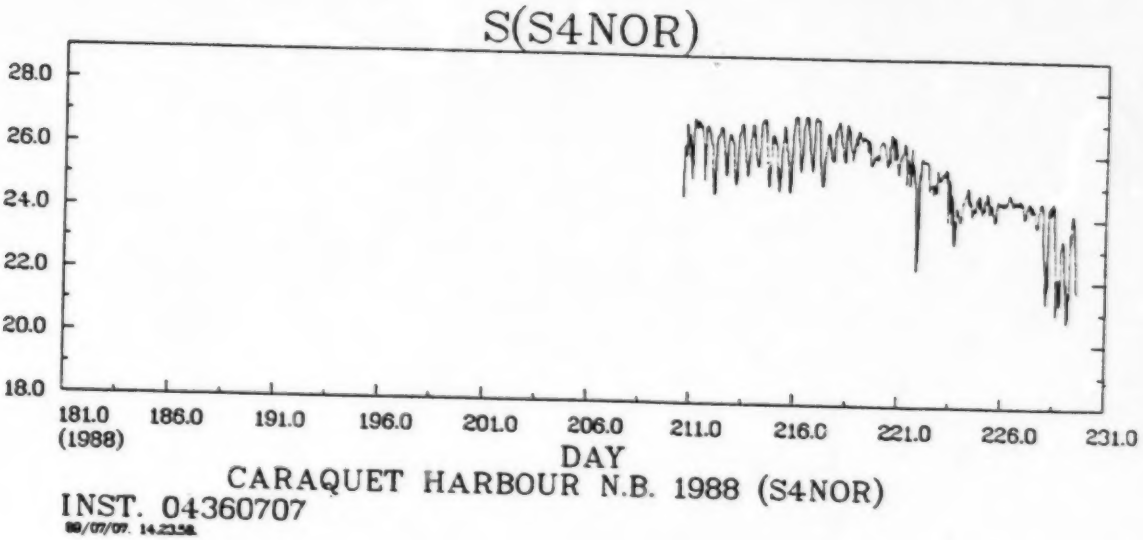


FIGURE 26. East (U) and north (V) water velocities at 1 m above the bottom at mooring N in Caraquet Bay in 1988. All days are Julian days.



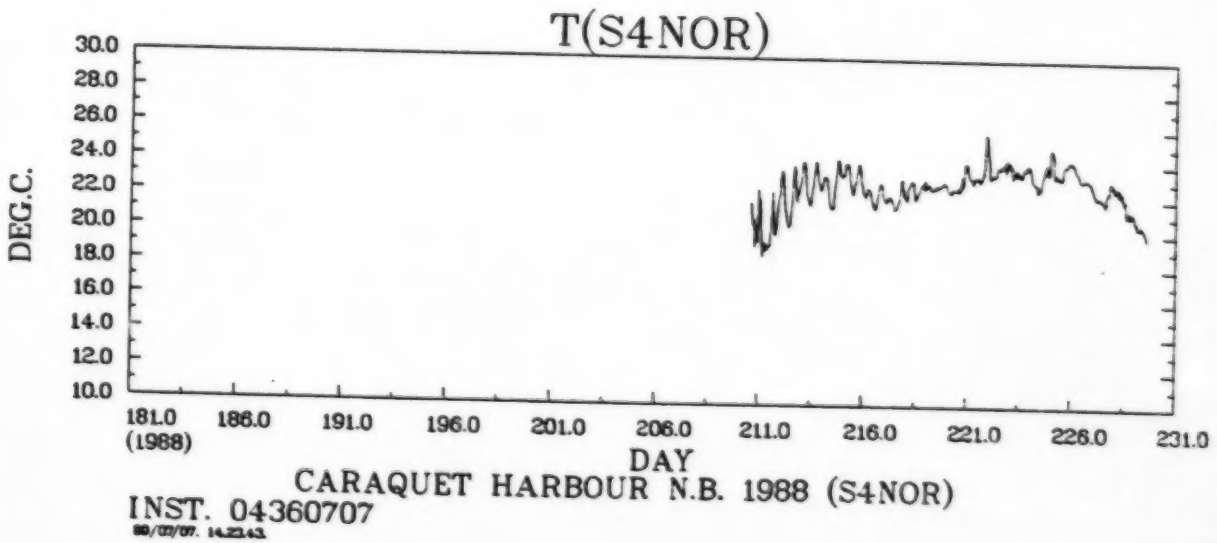
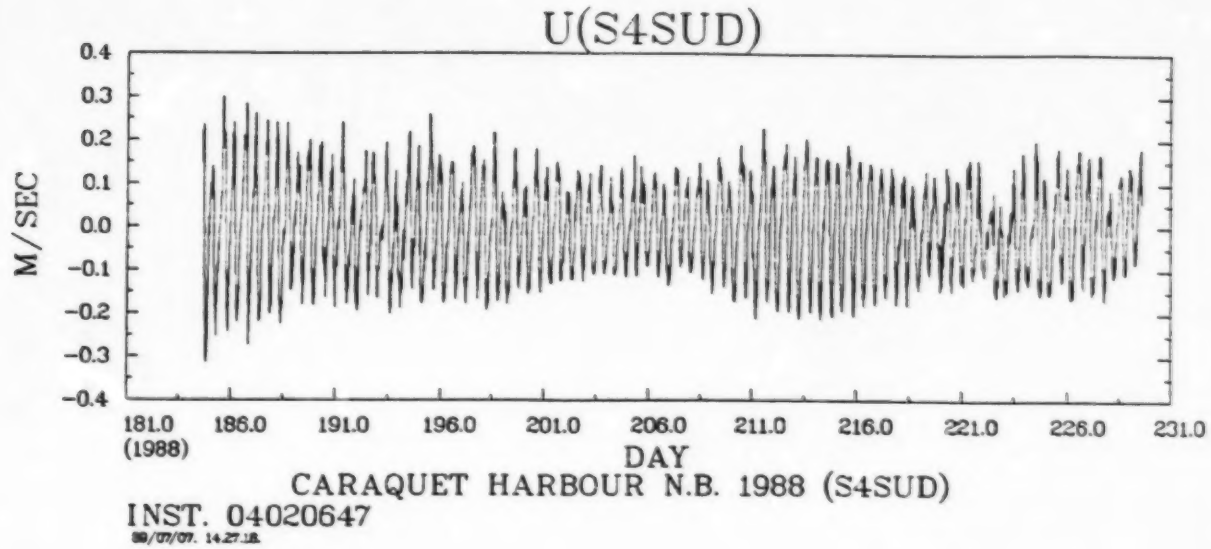


FIGURE 27. Salinity (S) and temperature (T) (°C) at 1 m above the bottom at mooring N in Caraquet Bay in 1988. All days are Julian days.



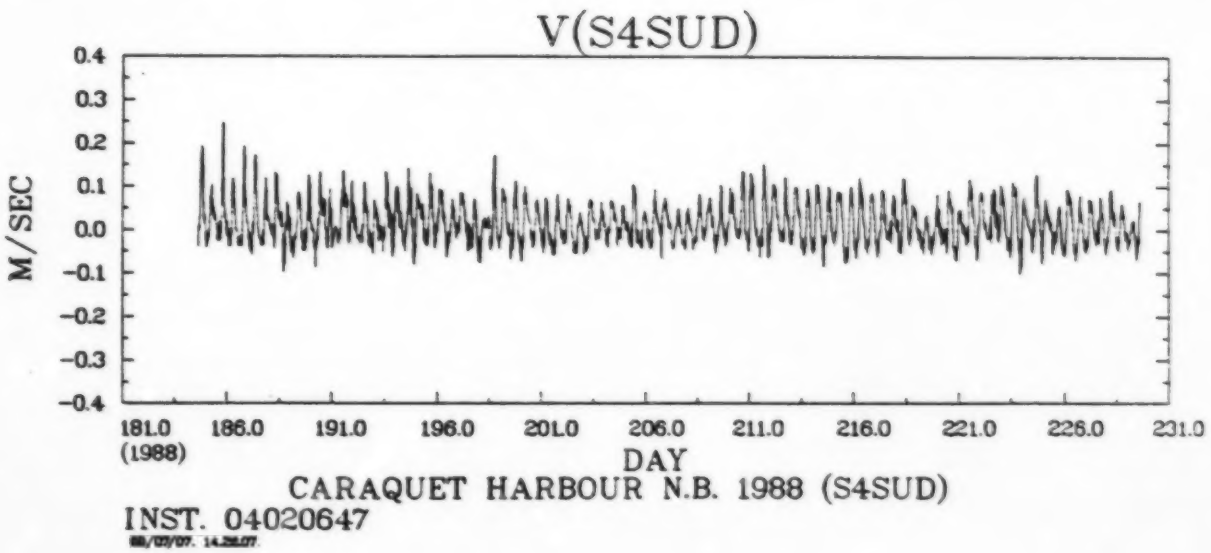
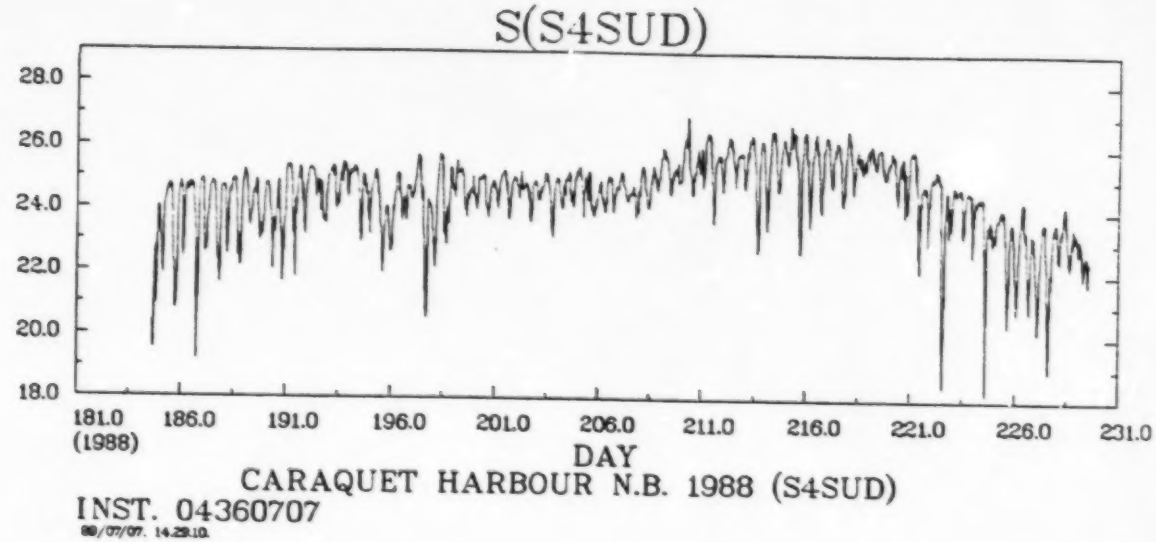


FIGURE 28. East (U) and north (V) water velocities at 1 m above the bottom at mooring S in Caraquet Bay in 1988. All days are Julian days.



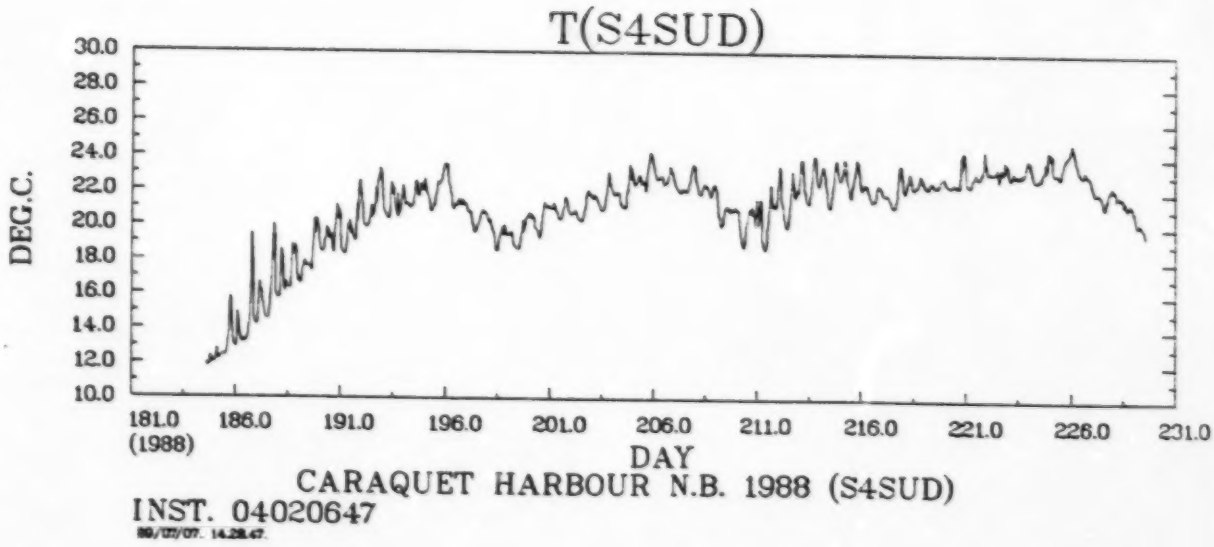
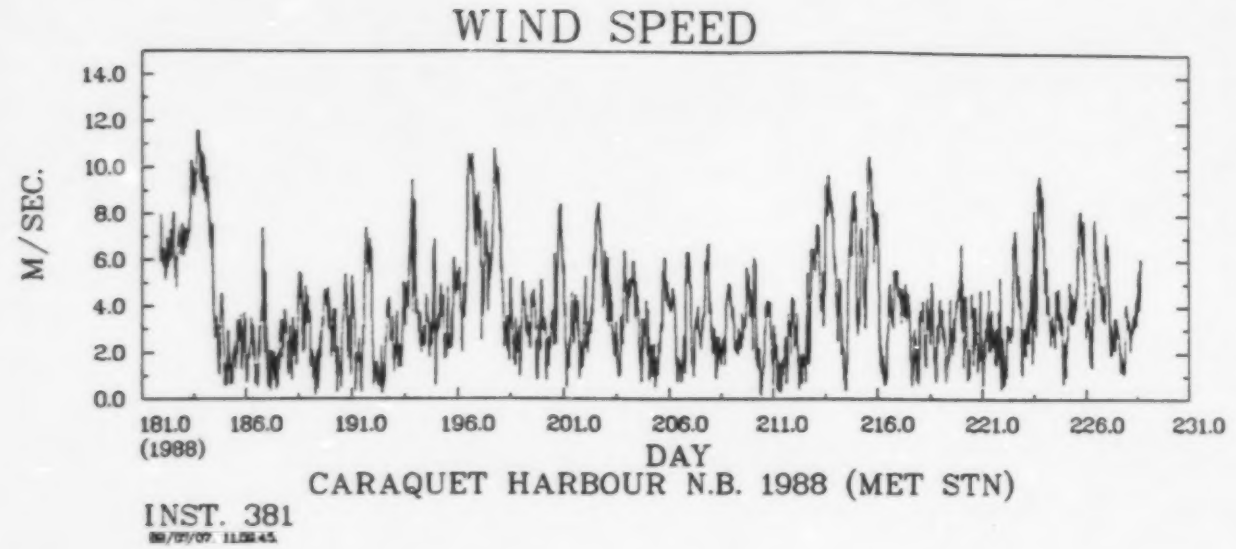


FIGURE 29. Salinity (S) and temperature (T) (°C) at 1 m above the bottom at mooring S in Caraquet Bay in 1988. All days are Julian days.



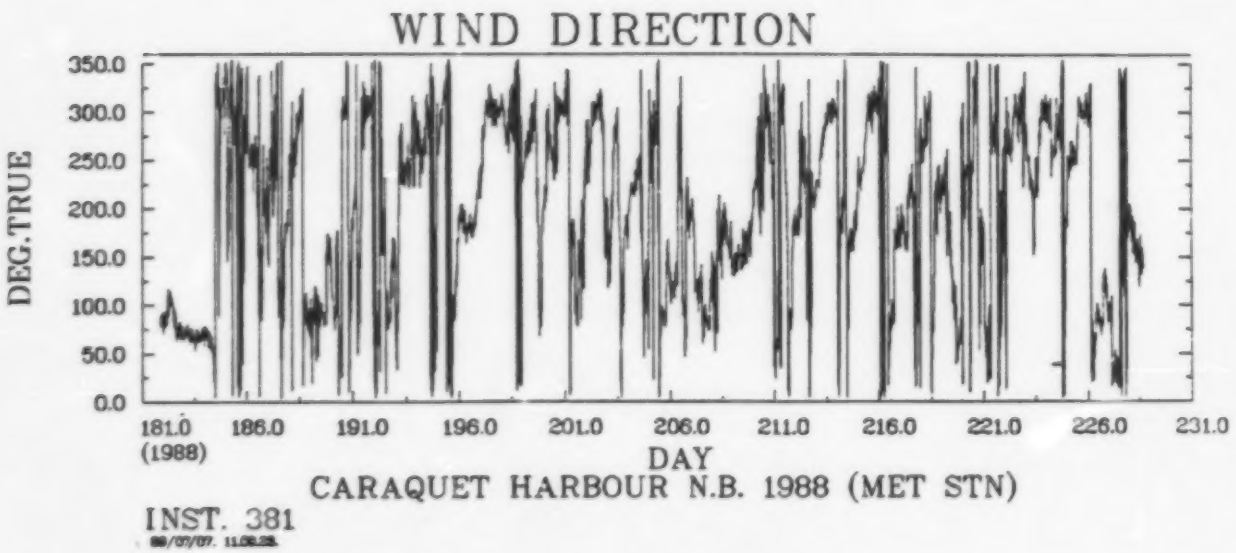
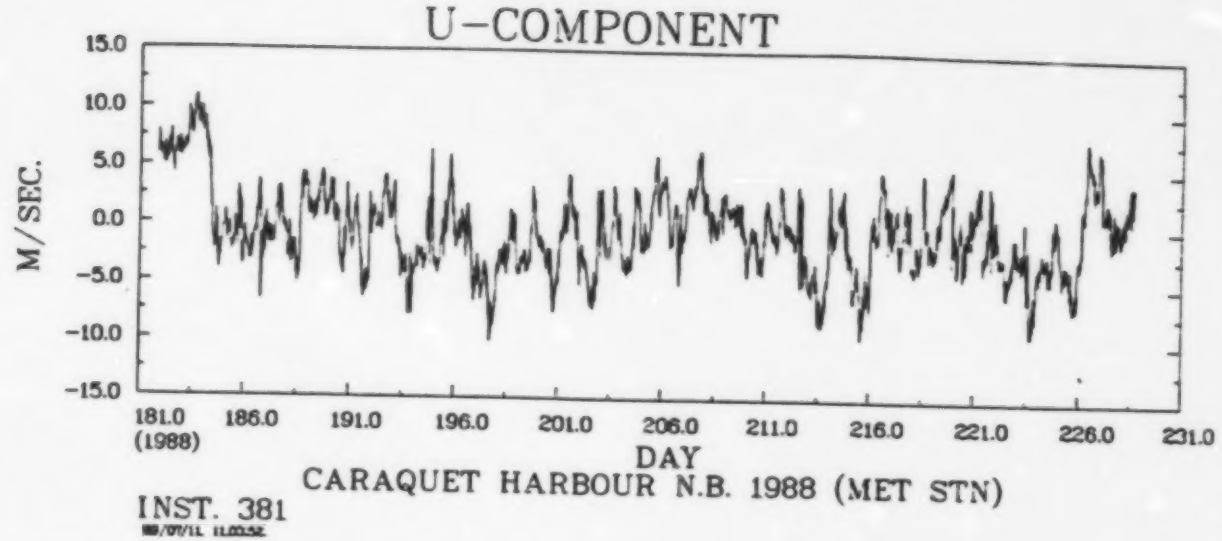


FIGURE 30. Wind speed and direction (towards) at 5 m above the ground at Oyster Point in Caraquet Bay in 1988. All days are Julian days.



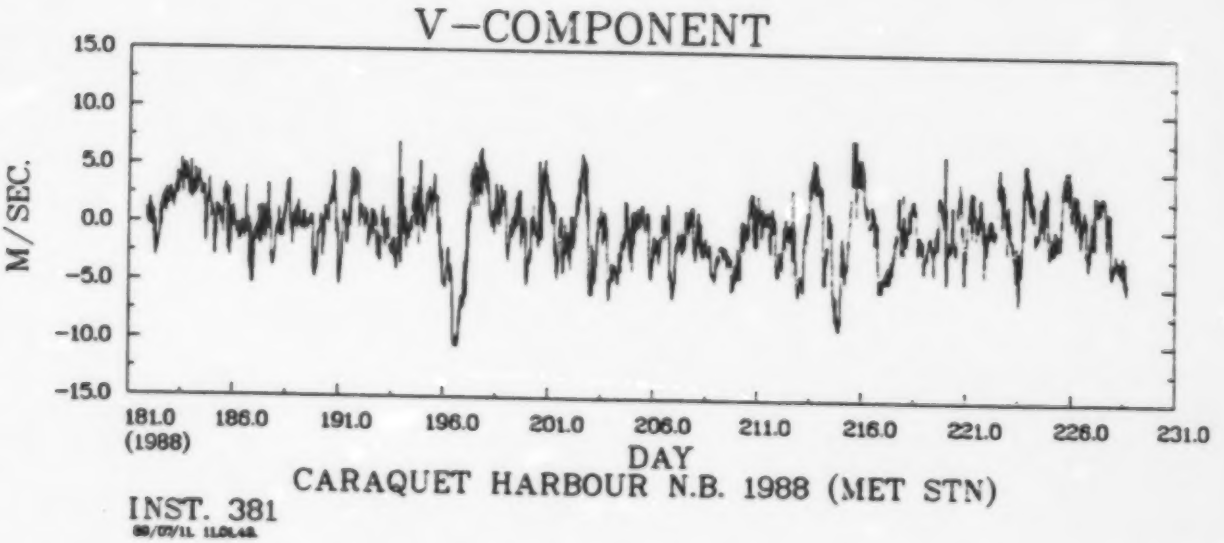
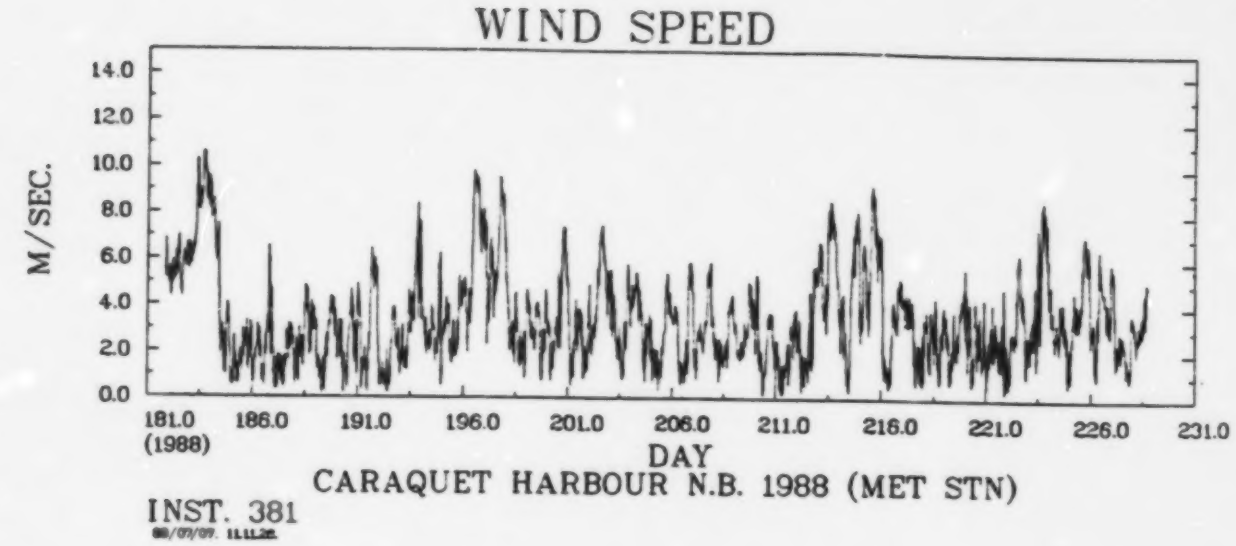


FIGURE 31. East (U) and north (V) wind velocities at 5 m above the ground at Oyster Point in Caraquet Bay in 1988. All days are Julian days.



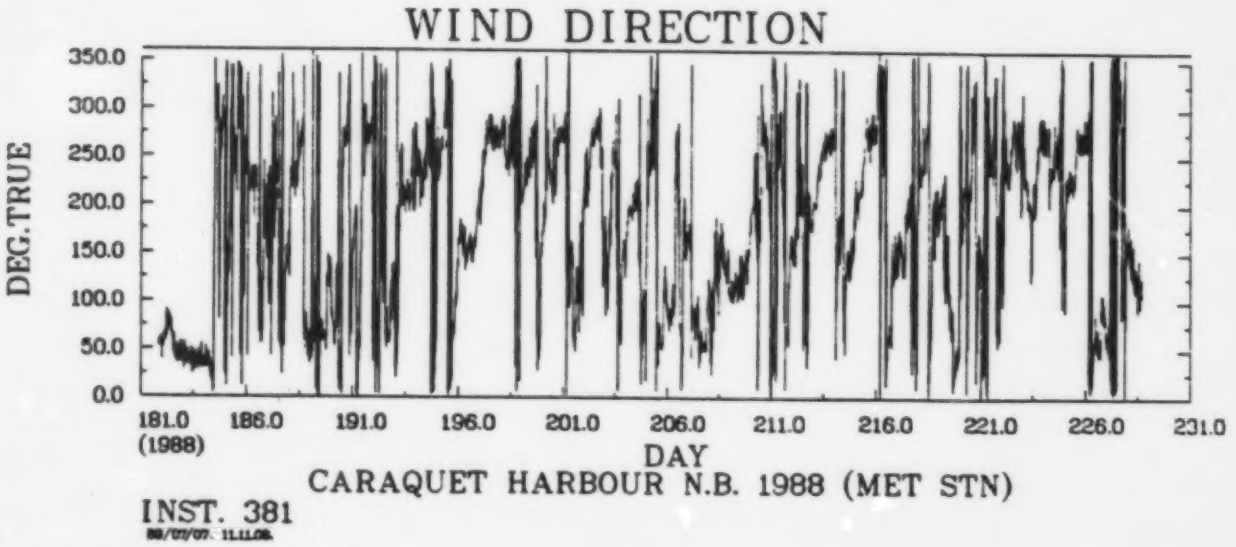
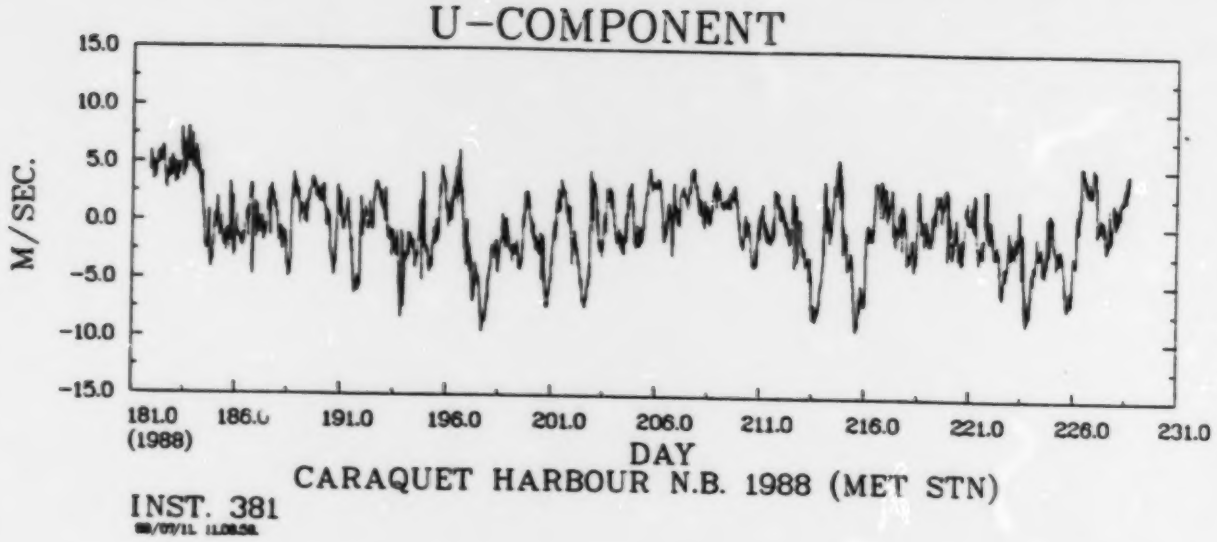


FIGURE 32. **Wind speed and direction (towards) at 2.5 m above the ground at Oyster Point in Caraquet Bay in 1988. All days are Julian days.**



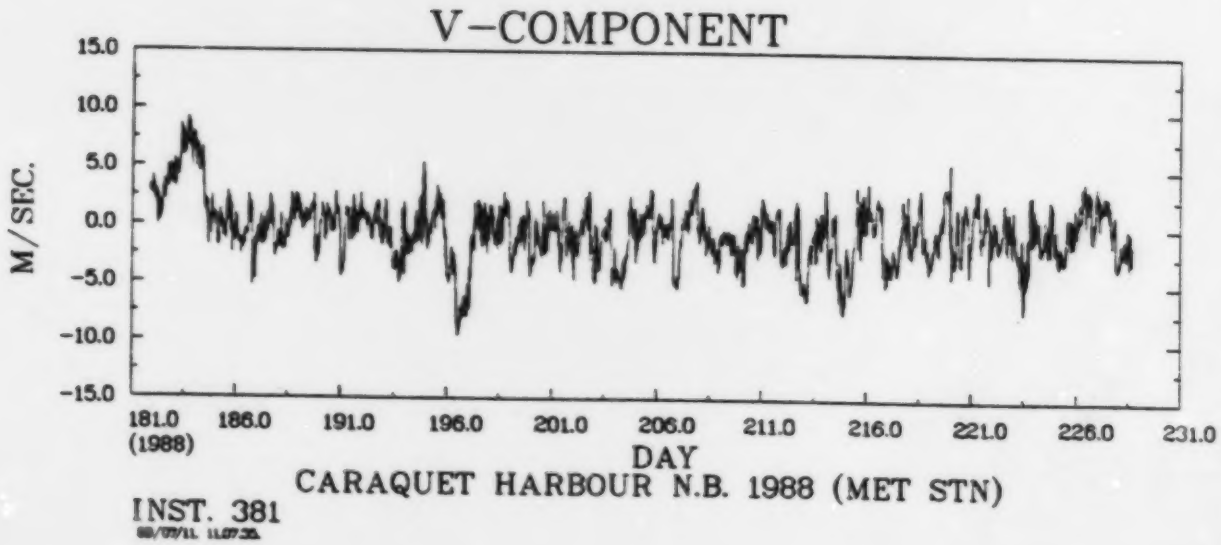
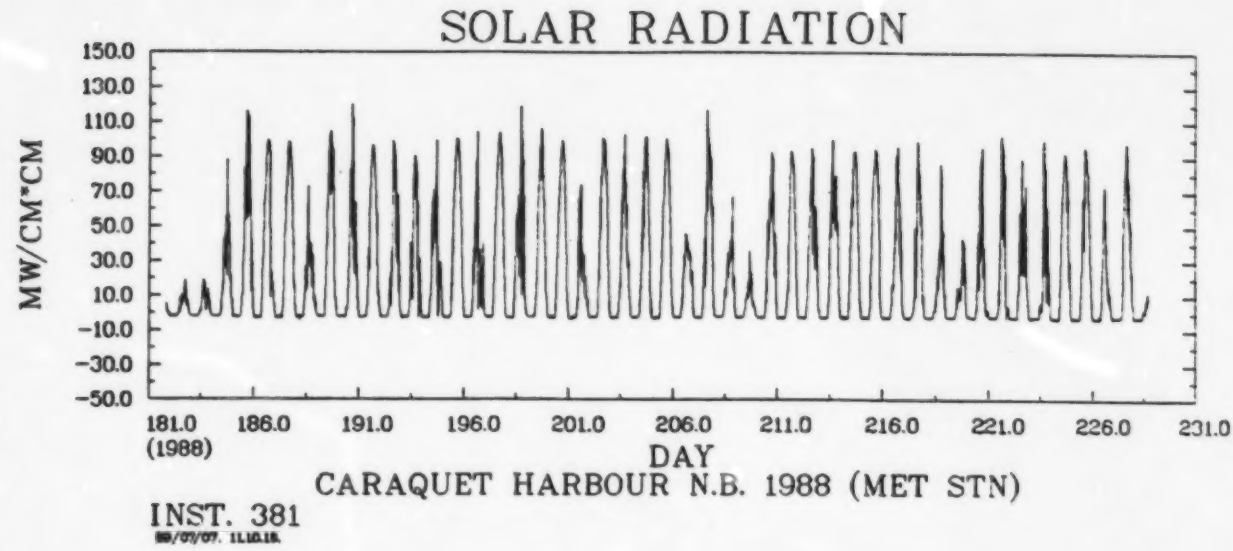


FIGURE 33. East (U) and north (V) wind velocities at 2.5 m above the ground at Oyster Point in Caraquet Bay in 1988. All days are Julian days.



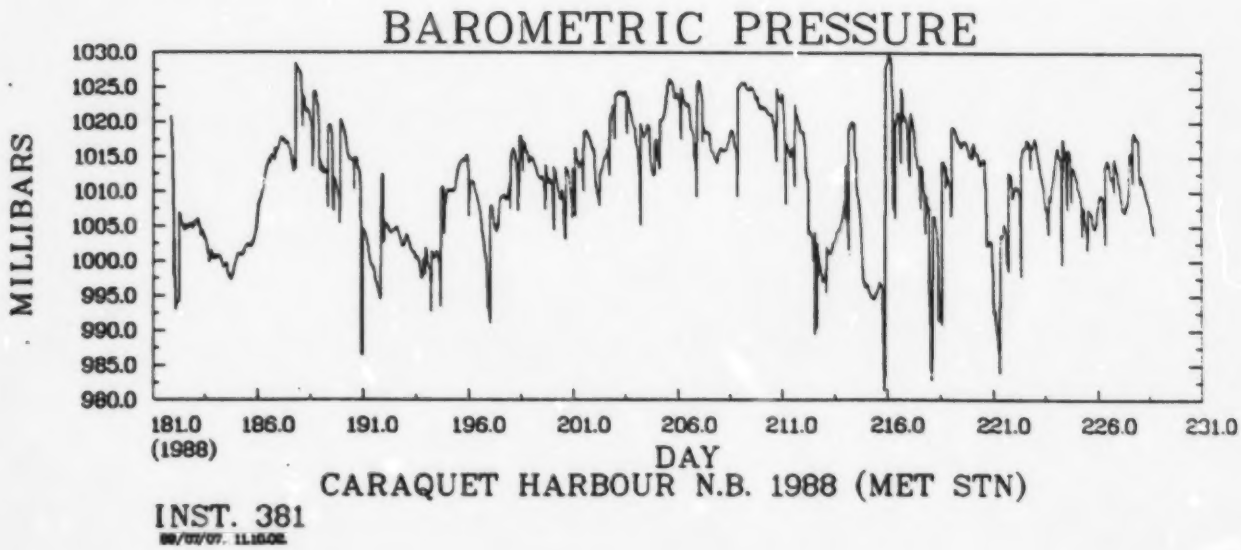
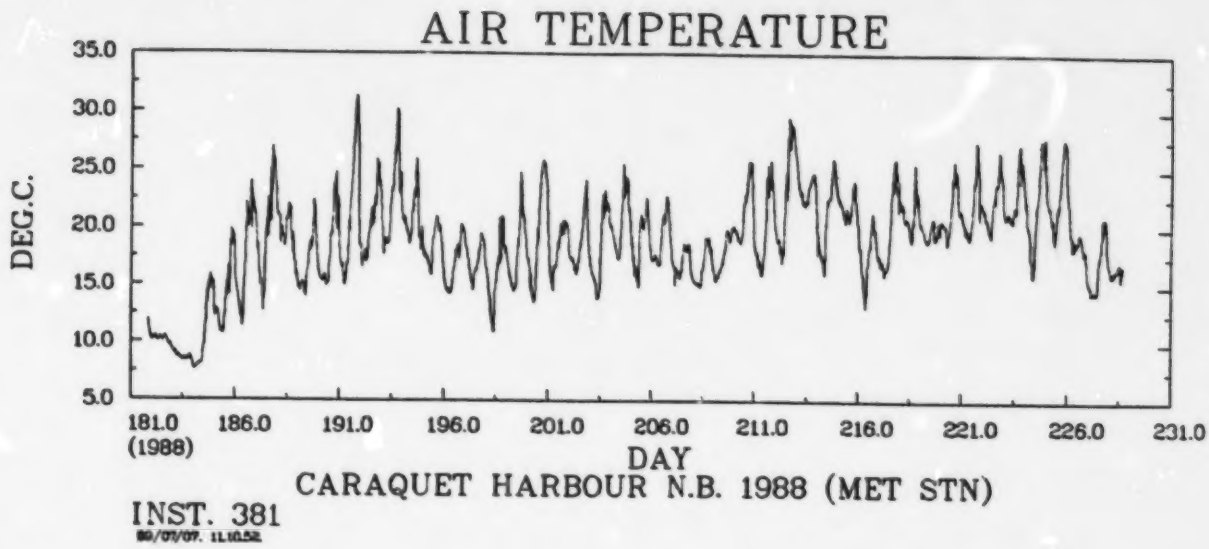


FIGURE 34. Solar radiation ($mW \cdot cm^{-2}$) and atmospheric pressure (mbar) at Oyster Point in Caraquet Bay in 1988. All days are Julian days.



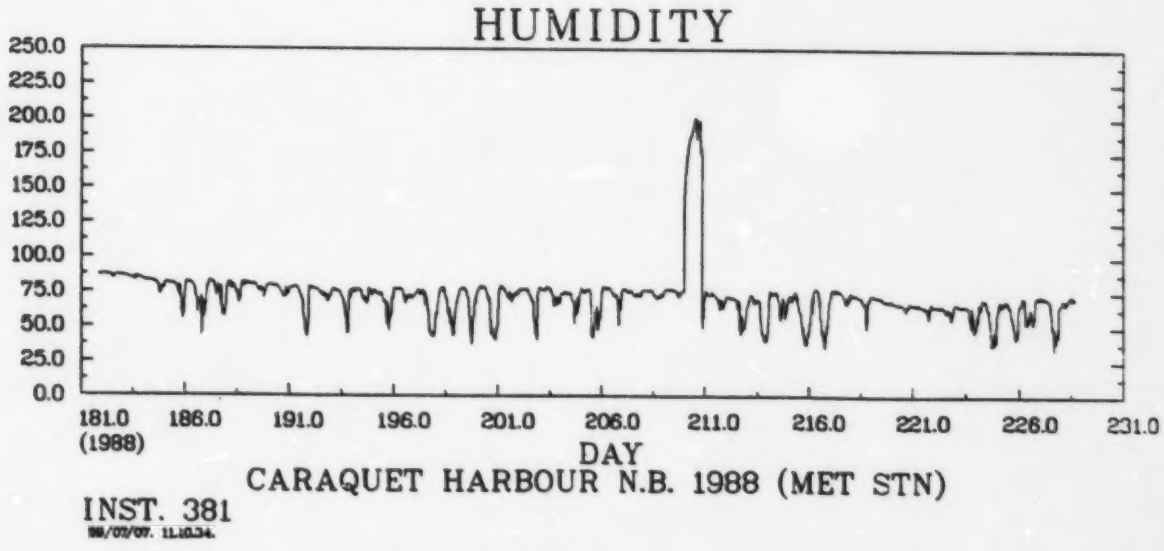


FIGURE 35. Air temperature (°C) and relative humidity (%) at Oyster Point in Caraquet Bay in 1988. All days are Julian days.

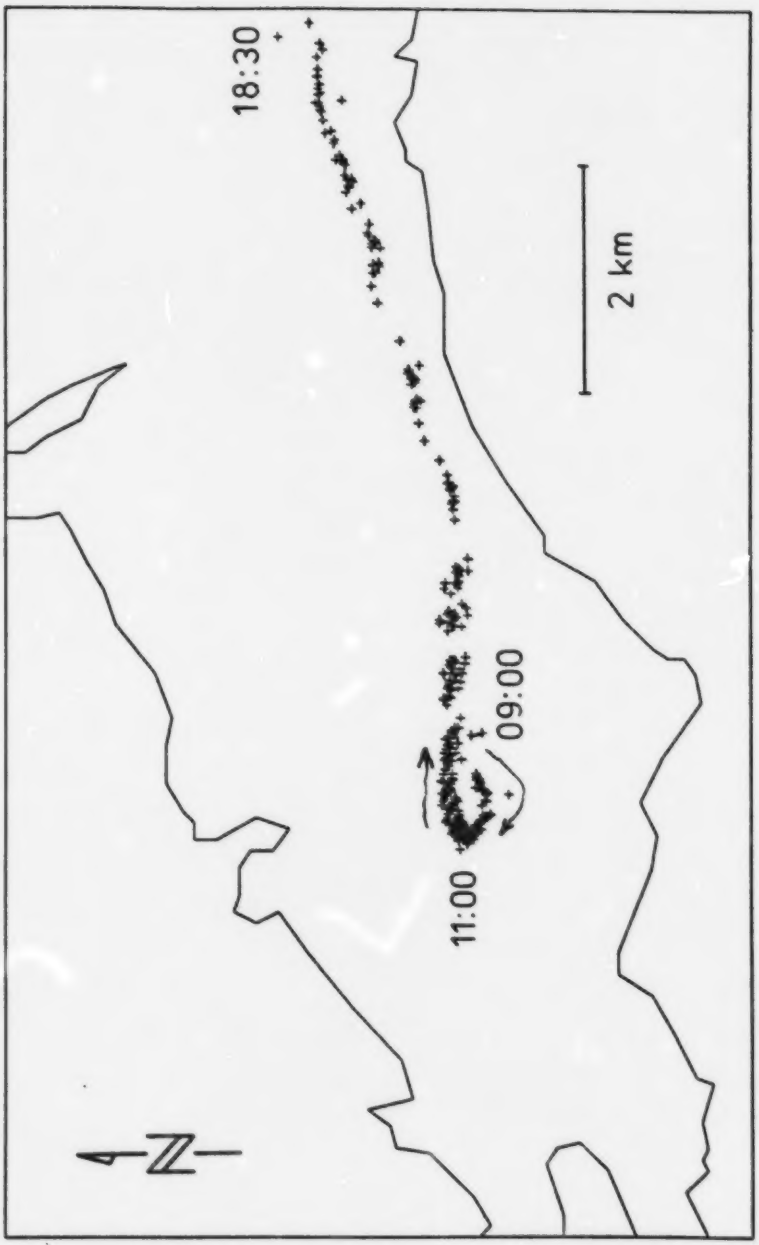


FIGURE 36. Data locations for drifting buoys released in Caraquet Bay on Julian day 187, 1988. The timing of low and high tides (time and pressure) was: 05:10 -0.62 db, 11:30 0.75 db, 18:40 -0.70 db. All times are in UTC.

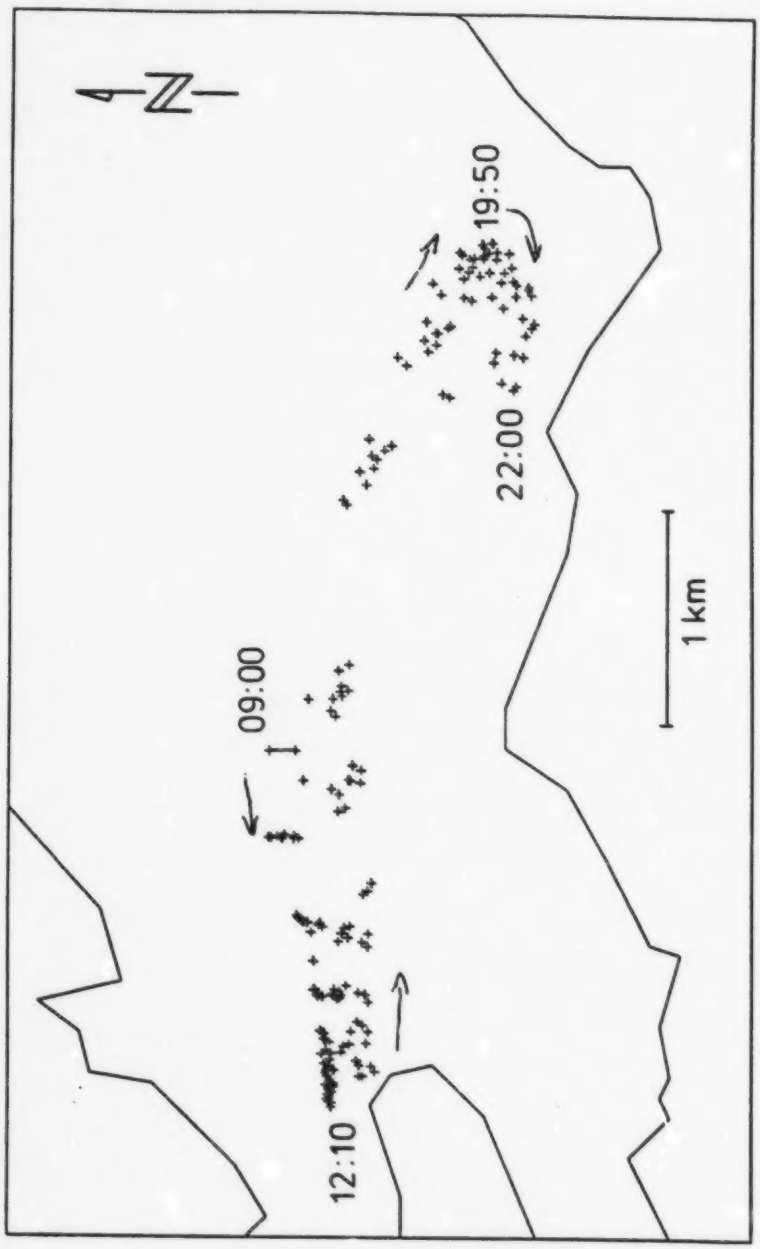


FIGURE 37. Data locations for the "northern group" of drifting buoys released in Caraquet Bay on Julian day 188, 1988. The timing of low and high tides (time and pressure) was: 06:20 -0.60 db, 12:10 0.58 db, 18:50 -0.54 db. All times are in UTC.

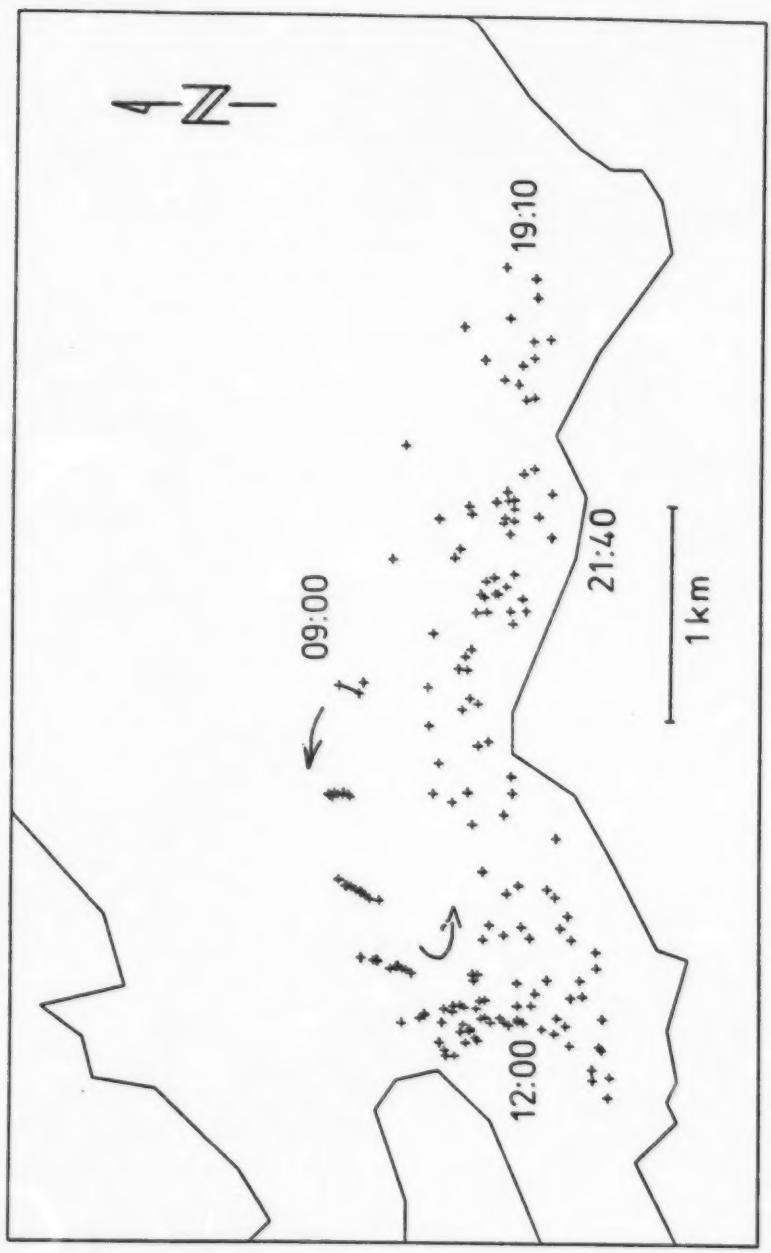


FIGURE 38. Data locations for the "southern group" of drifting buoys released in Caraquet Bay on Julian day 188, 1988. The timing of low and high tides (time and pressure) was: 06:20 -0.60 db, 12:10 0.58 db, 18:50 -0.54 db. All times are in UTC.

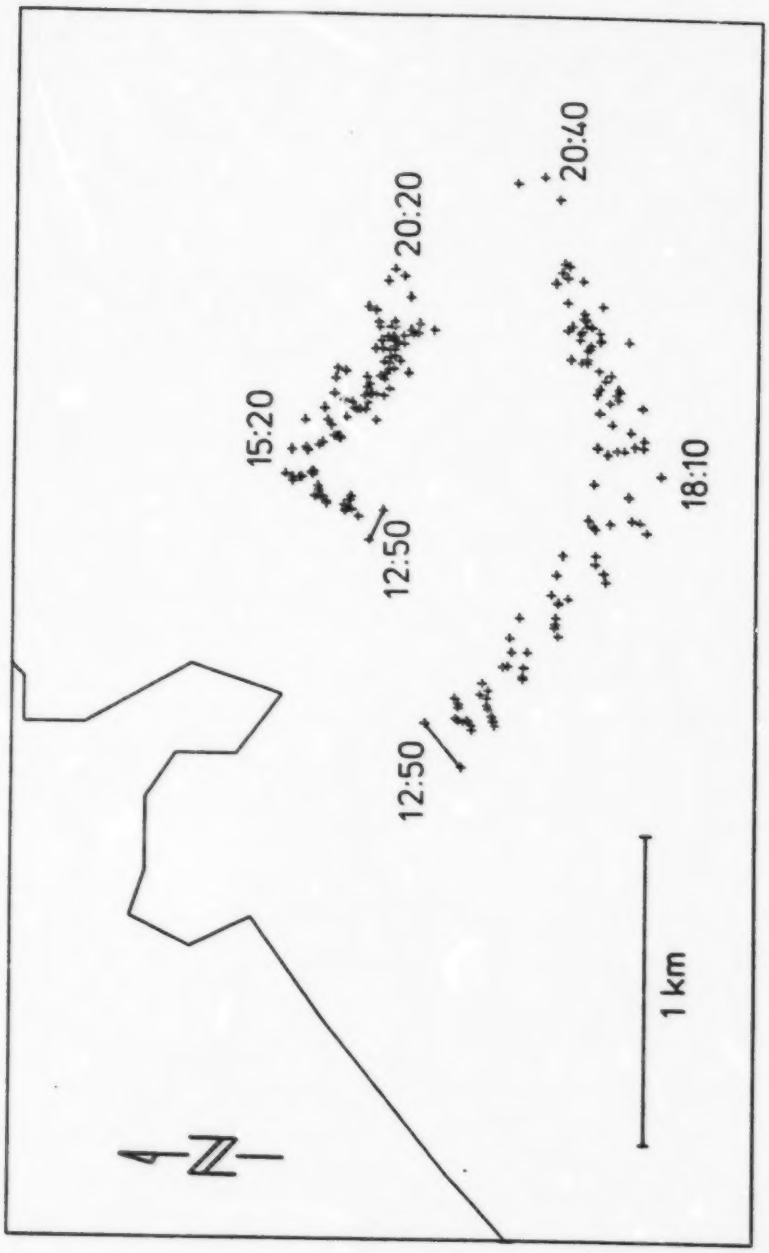


FIGURE 39. Data locations for the two groups of drifting buoys released in Caraquet Bay on Julian day 189, 1988. The timing of low and high tides (time and pressure) was: 07:30 -0.47 db, 13:20 0.36 db, 19:30 -0.57 db. All times are in UTC.

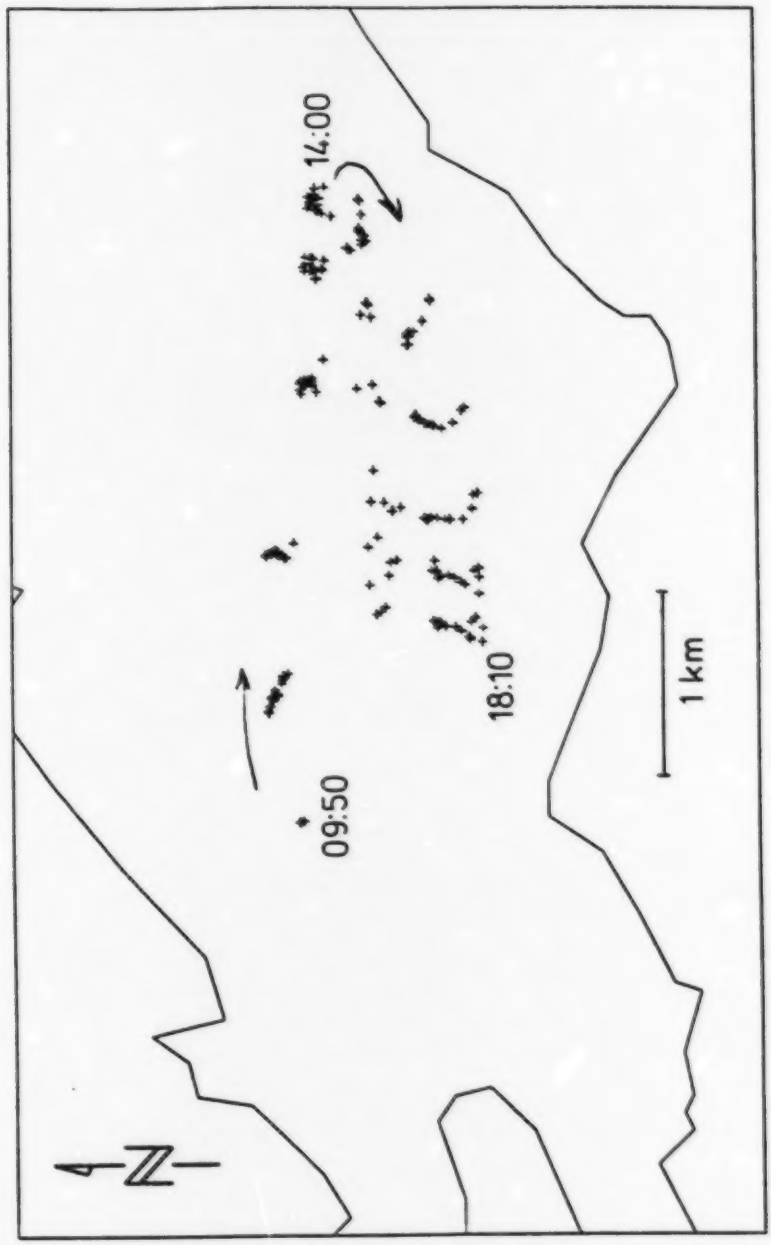


FIGURE 40. Data locations of drifting buoys released in Caraquet Bay on Julian day 194, 1988. The timing of low and high tides (time and pressure) was: 06:00 0.95 db, 14:00 -0.65 db, 18:20 0.10 db. All times are in UTC.

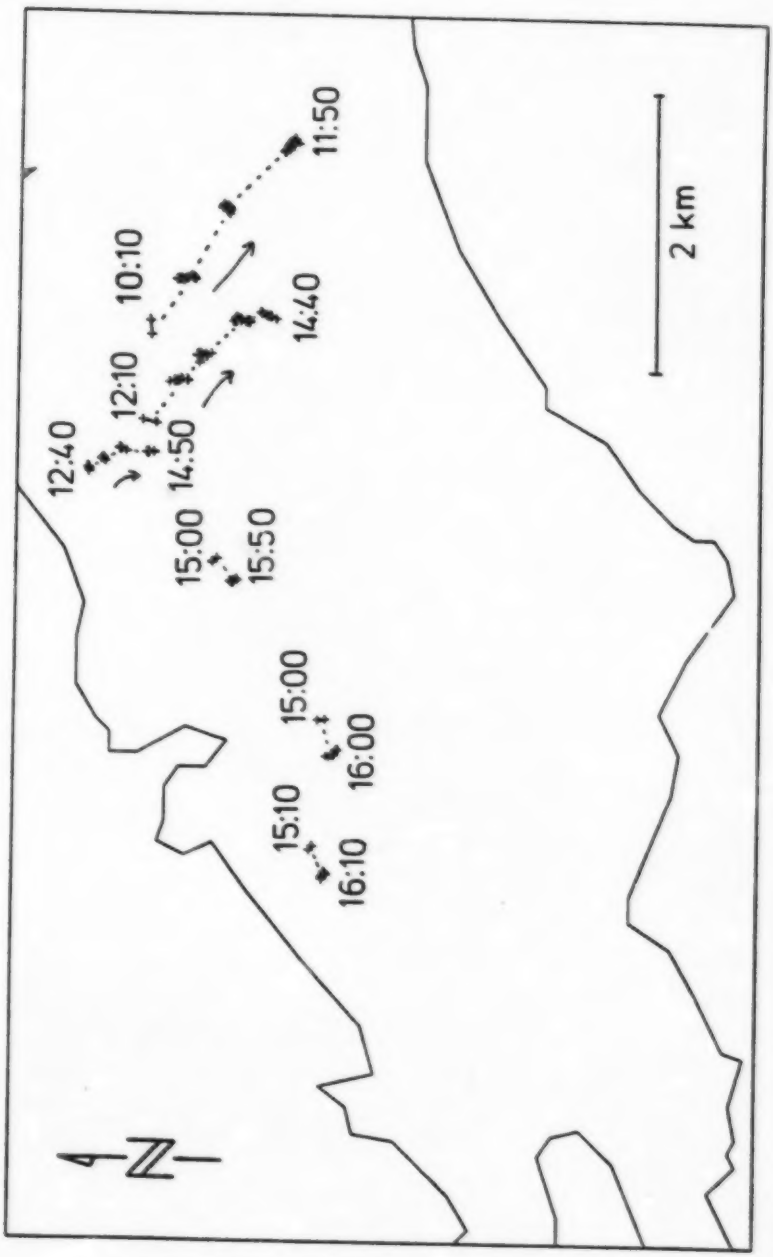


FIGURE 41. Data locations for the different groups of drifting buoys released in Caraquet Bay on Julian day 195, 1988. The timing of low and high tides (time and pressure) was: 06:50 1.02 db, 14:10 -0.53 db, 19:20 0.13 db. All times are in UTC.

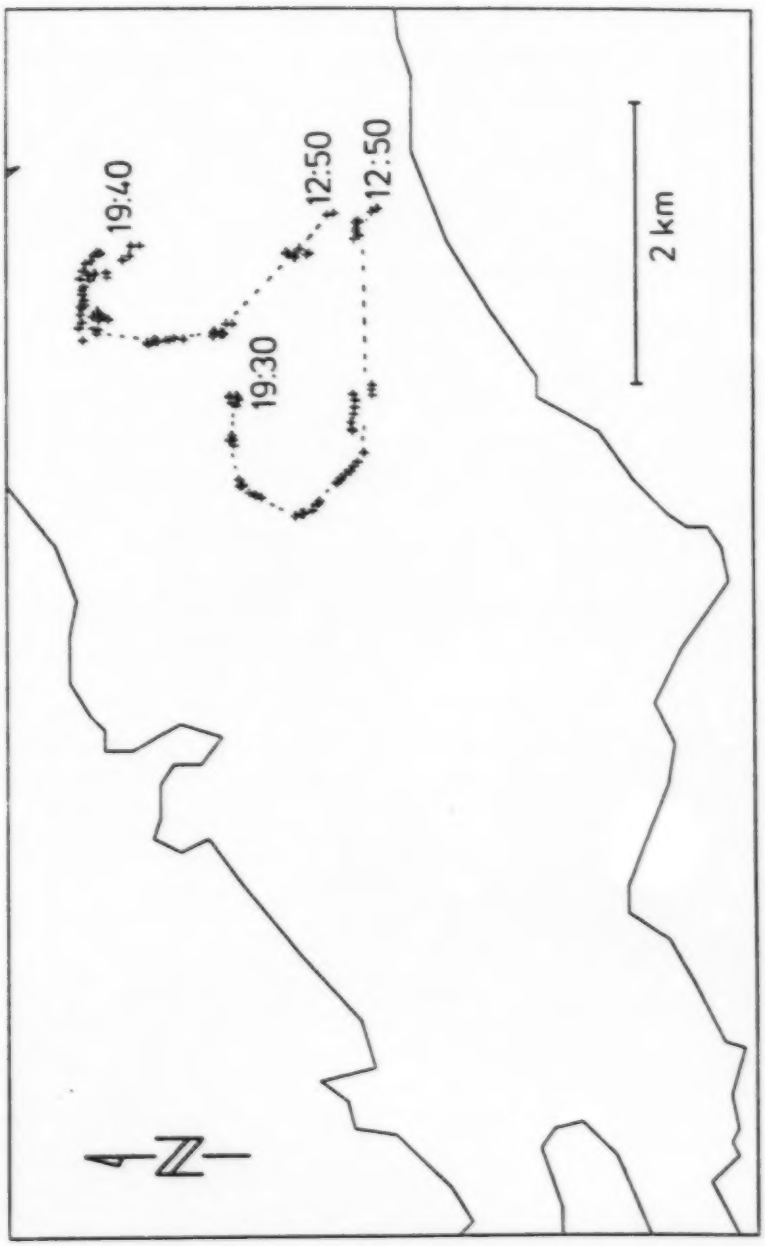


FIGURE 42. Data locations for the drifting buoys released in Caraquet Bay on Julian day 208, 1988. The timing of low and high tides (time and pressure) was: 11:40 -0.50 db, 17:10 0.02 db, 22:10 -0.49 db. All times are in UTC.

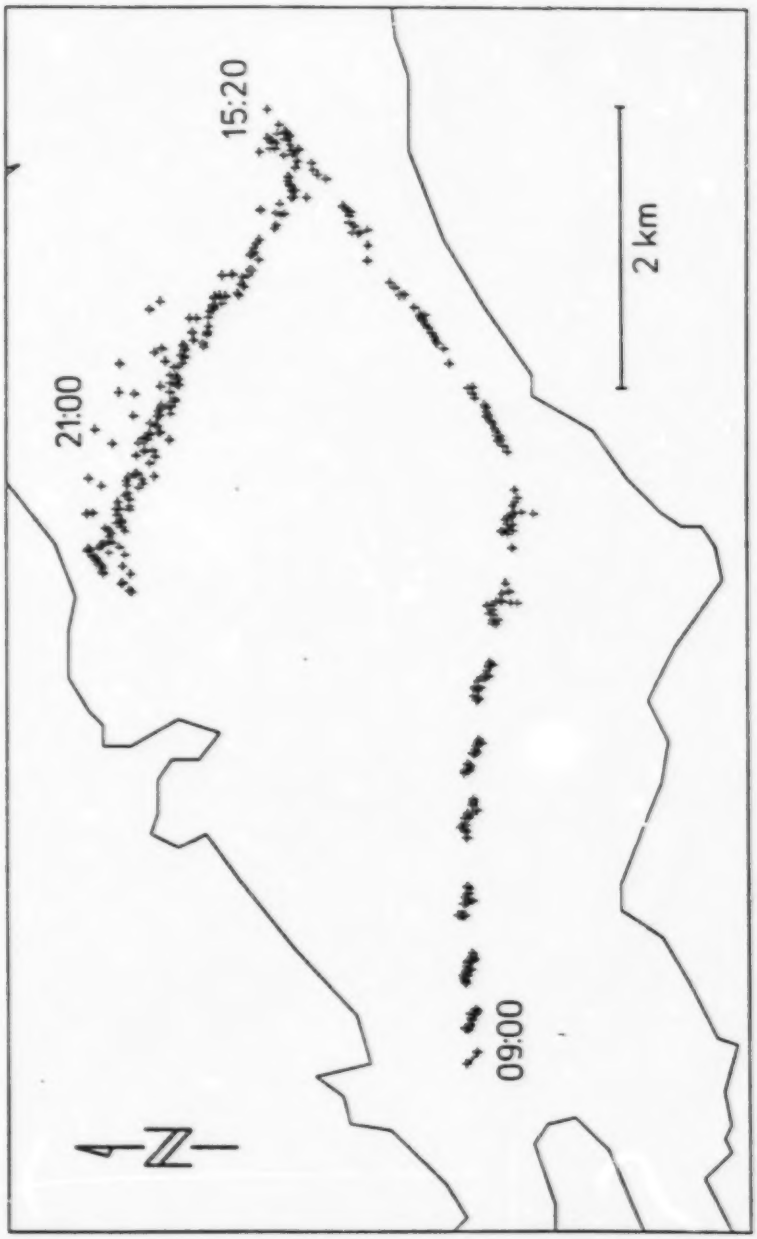


FIGURE 43. Data locations for the drifting buoys released in Caraquet Bay on Julian day 211, 1988. The timing of low and high tides (time and pressure) was: 06:50 1.07 db, 14:50 -0.79 db, 19:30 0.22 db. All times are in UTC.

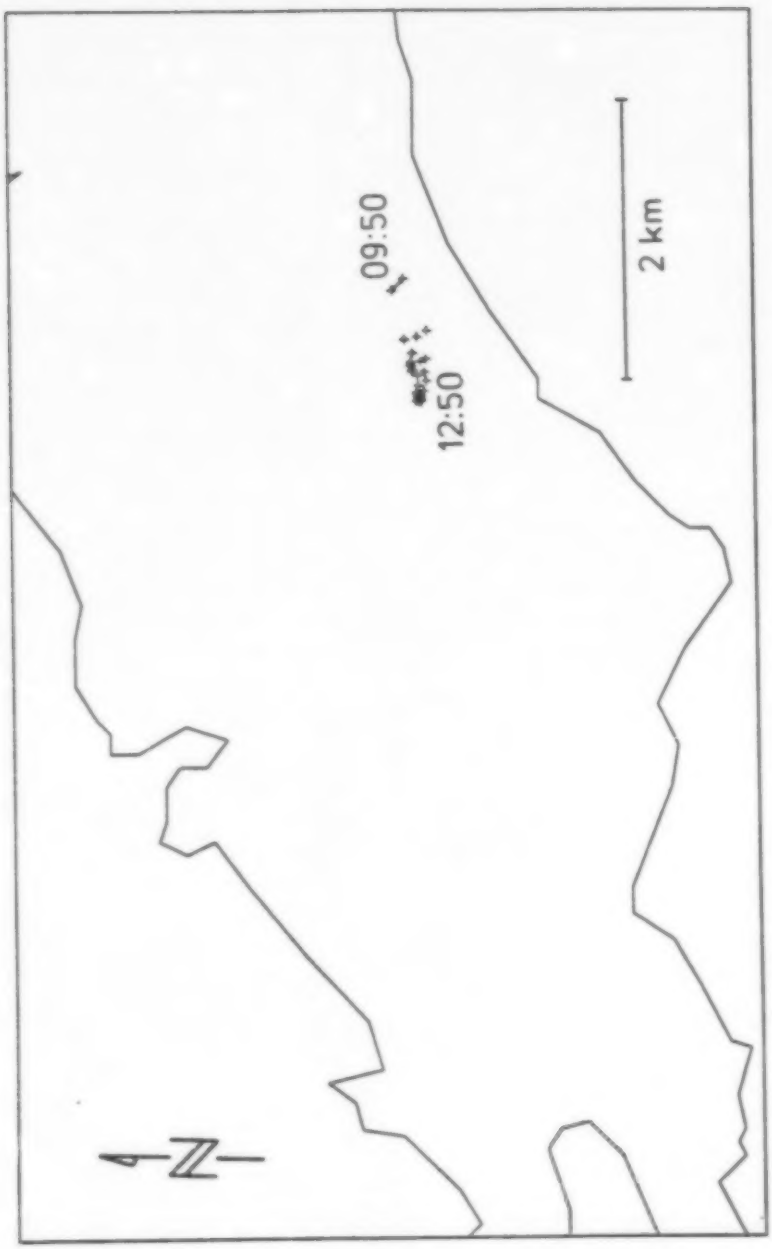


FIGURE 44. Data locations for the drifting buoys released in Caraquet Bay on Julian day 215, 1988. The timing of low and high tides (time and pressure) was: 04:30 -0.72 db, 10:50 0.81 db, 17:20 -0.78 db. All times are in UTC.

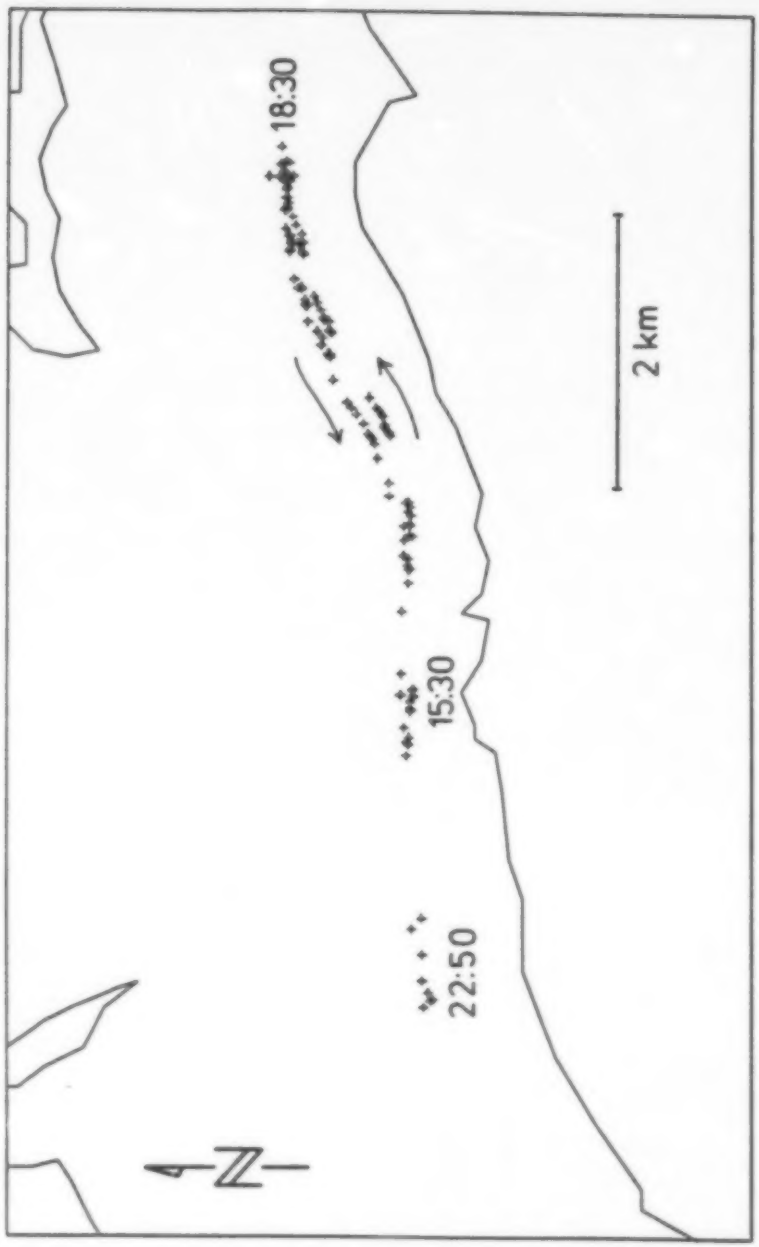


FIGURE 45. Data locations for the drifting buoys released at the entrance (channel) to Caraquet Bay on Julian day 216, 1968. The timing of low and high tides (time and pressure) was: 11:20 0.65 db, 18:00 -0.52 db, 23:30 0.75 db. All times are in UTC.

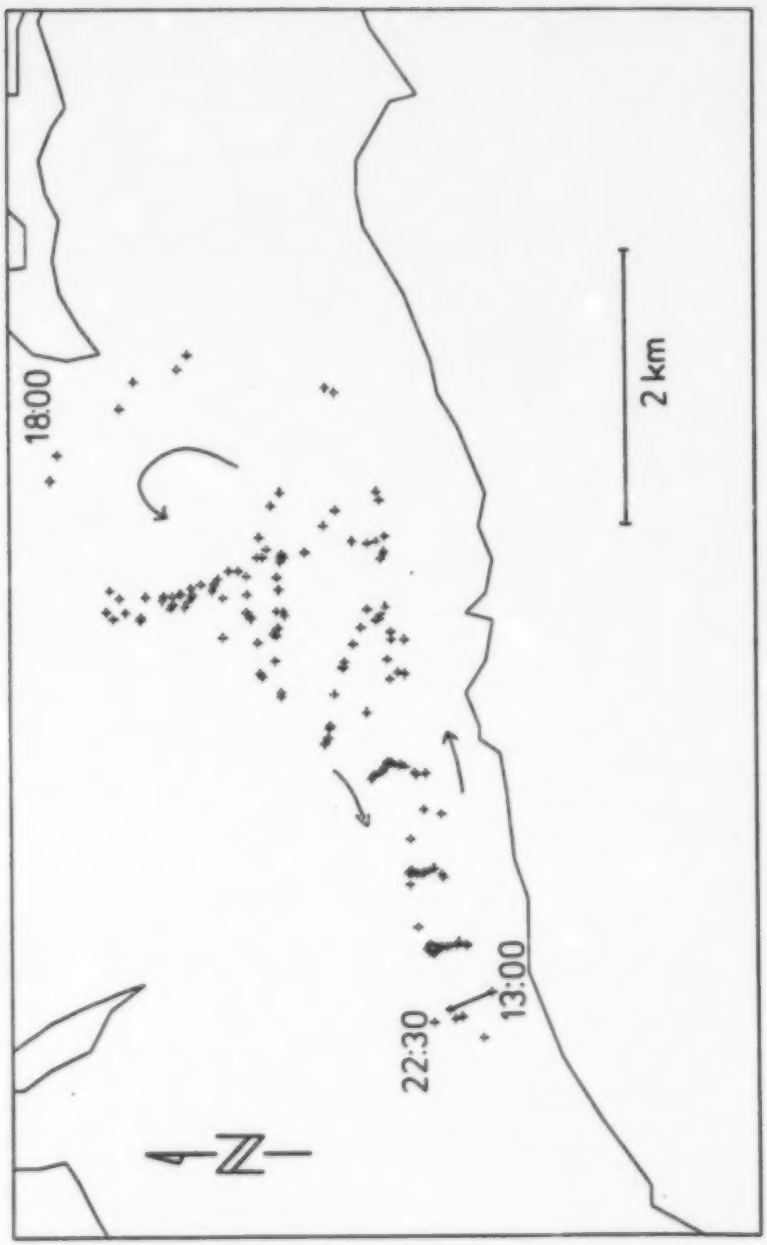


FIGURE 46. Data locations for the drifting buoys released at the entrance (channel) to Caraquet Bay on Julian day 217, 1988. The timing of low and high tides (time and pressure) was: 11:50 0.40 db, 17:50 -0.56 db, 24:10 0.65 db. All times are in UTC.